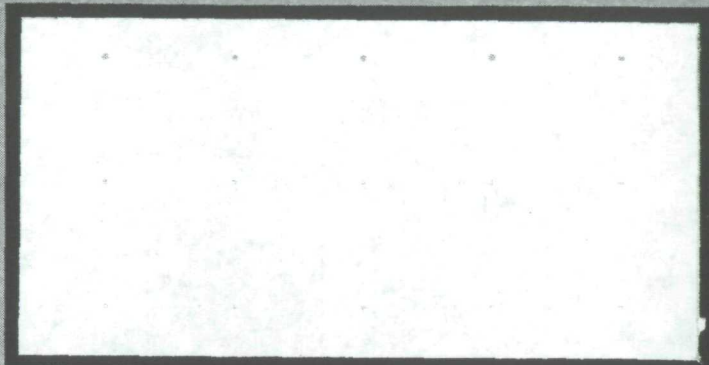


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(NASA-CR-128885) SHUTTLE MISSION  
SIMULATOR HARDWARE CONCEPTUAL DESIGN  
REPORT (Singer Co., Binghamton, N.Y.)  
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SIMULATION PRODUCTS

A DIVISION OF THE SINGER COMPANY • DEVELOPER AND MANUFACTURER OF THE **LINK** TRAINER SINCE 1929

SHUTTLE MISSION SIMULATOR

HARDWARE CONCEPTUAL

DESIGN REPORT

3/23/73

*J. F. Burke*  
\_\_\_\_\_  
J. F. Burke  
Principal Investigator  
SMS Definition Study

This document is submitted in compliance with Line Item No. 7  
of the Data Requirements List as Type I Data, Contract NAS9-12836

SINGER COMPANY  
SIMULATION PRODUCTS DIVISION

SHUTTLE MISSION SIMULATOR  
HARDWARE CONCEPTUAL  
DESIGN REPORT

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Preface

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Data Requirements List as Type I Data, Contract NAS9-12836.



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TABLE

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SMS DCE Requirements

## 1. Introduction

The purpose of this report is to identify the detailed Shuttle Mission Simulator hardware requirements which have resulted from the requirements specified in the SMSR Report, and to describe the conceptual design methods, or existing hardware, whereby those requirements will be fulfilled. The report provides information of a general nature on the total design problem plus specific details on how these requirements are to be satisfied. This document, in conjunction with the SMS Software Conceptual Design Report, will lay the ground work for defining the Baseline Shuttle Mission Simulator.

An in depth analysis of the Shuttle Mission Simulator training requirements has been made as part of the SMSR Report generation analysis, and as a result, a definition of the training devices required in the SMS complex has been determined, and serves as a starting point for this report. In conjunction with the training requirements analysis, a Crew Station, motion and visual trade study was conducted which arrived at the conclusion that state-of-the-art motion systems could not support a replica of the entire Orbiter upper crew station, a forward and aft visual system, and provide the vertical crew station attitudes required for launch and launch abort training. Significant results of this trade study are briefly described in Section 4.1. As a result of these studies and subsequent review meetings with the NASA, the SMS complex has been specified to consist of two independent crew stations. One crew station, which

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will be referred to as the Motion Base Crew Station (MBCS) will be used to train the Commander and Pilot in all phases of the mission except Docking and Payload Handling operations. The second crew station, which will be referred to as the Fixed Base Crew Station (FBCS), will provide training for the Commander, Pilot, Mission Specialist, and Payload Specialist at all upper crew compartment work stations in all mission phases. Refer to Figure 1-1, which identifies the major equipment areas of the SMS.

The MBCS will be mounted on a six DOF motion system provided with a tilt capability to simulate ascent. A visual system will provide the scenes required for those phases of the mission listed above. The FBCS will be mounted on a fixed platform. A forward and an aft visual system will be included to provide the scenes required for all mission phases.

Training in the MBCS will be conducted independent of the FBCS and vice versa. Training on different exercises can be conducted simultaneously in both crew stations. Current planning calls for the MBCS to be required earlier than the FBCS and to support the initial two man vertical flight tests. When the FBCS becomes operational, it will be used primarily for on-orbit training due to the lack of motion cues considered necessary for aerodynamic flight training in an airplane type vehicle such as the Orbiter. However, the capability to provide training in the FBCS during the aerodynamic flight regimes is a requirement in order to provide back-up capability in case the



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MBCS is not operational due to maintenance or modification requirements and to handle integrated (MCC) exercises if crew procedures subsequently require three or four man participation during the aerodynamic flight regimes. Conversely the primary function of the MBCS will be to provide Commander/Pilot training for launch, launch aborts, entries and ferry flights. Thus significant cost savings may be effected if the SMS design philosophy recognizes the primary and back-up roles of each crew station. These savings can be brought about by sharing equipment between the two crew stations which are unique to the orbital/sub-orbital mission segments. Potential candidates for sharing are the sub-orbital image generation equipment and the main engine controllers. On-orbit image generation equipment may also be considered, but it may seriously hamper the training flexibility of the MBCS and should only be considered if drastic cost reductions are required.

The SMS complex will also permit training in each crew station while integrated with MCC. The capability to operate both crew stations simultaneously with MCC has not been firmly decided. The key factor influencing this requirement is the capability of the non-SMS interfacing equipment (MCC and the inter-building communication equipment) to permit this type of operation.

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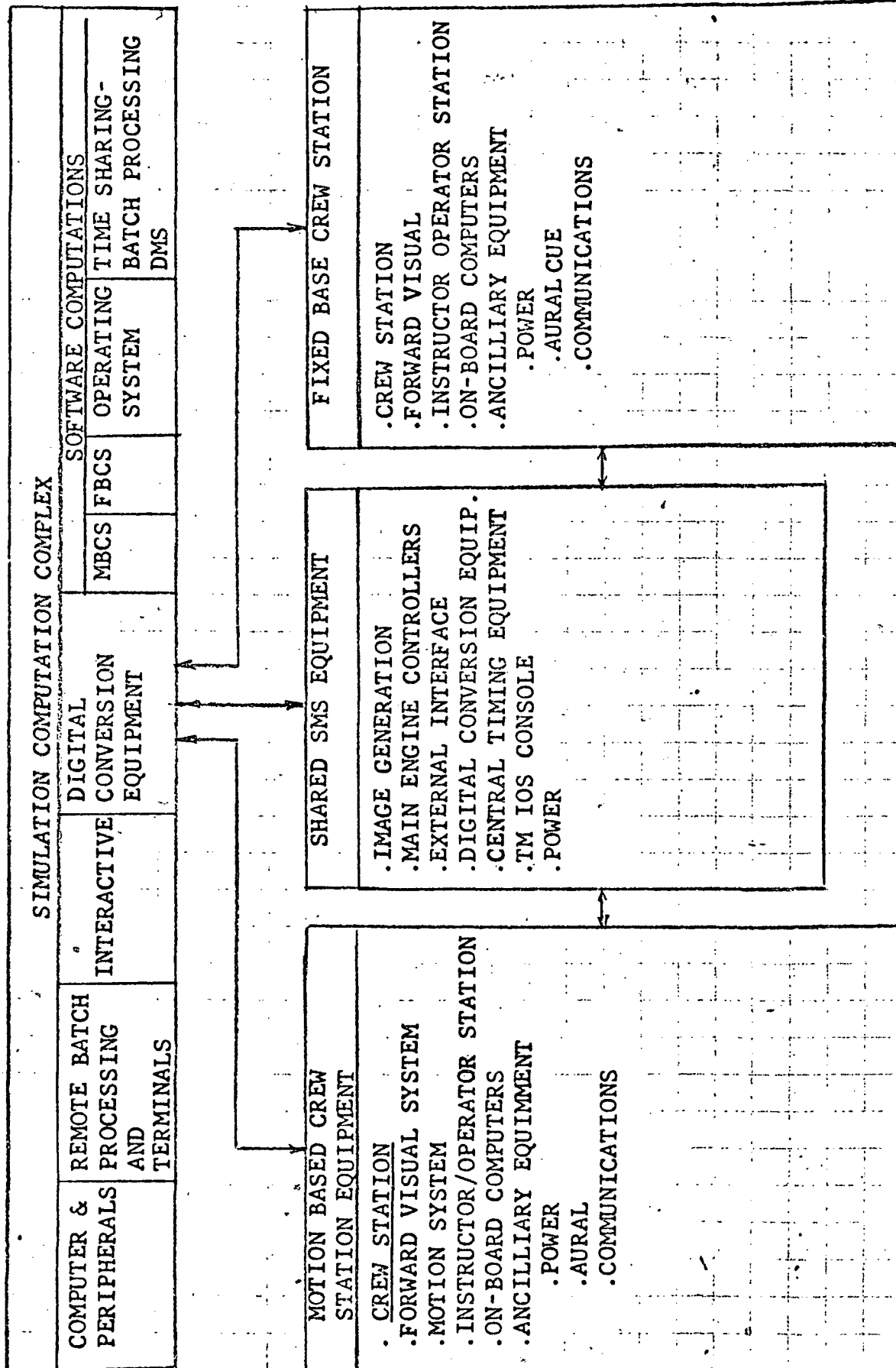


FIGURE 1-1  
SHUTTLE MISSION SIMULATOR MAJOR EQUIPMENT AREAS

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## 2. Applicable Documents

The following documents have been used as reference in identifying the requirements of the SMS.

1. Shuttle Vehicle and Mission Simulation Requirements Report
2. Shuttle Mission Simulator Requirements Report
3. Shuttle Mission Simulation Training Requirements Report
4. Shuttle Mission Simulator Software Conceptual Design Report
5. MIL-STD-1310 Shipboard Bonding and other techniques for Electromagnetic Compatibility and Safety
6. MIL-B-5087 Bonding, Electrical, and Lighting Protection, for Aerospace System
7. NHB 5320.3 Electromagnetic Compatibility Principles and Practices

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### 3. The Simulator Hardware Design Problem

The SMS must provide training for Shuttle Vehicle crew members and Mission Control Center personnel in all mission phases and vehicle operating modes in the most efficient and economical manner possible.

From a simulator hardware viewpoint, consideration must be given to the requirements and existing state-of-the-art capabilities of motion system hardware, visual system, crew station hardware, Instructor Operator Station hardware, Digital Computation Systems, and Data Conversion Equipment.

This report will discuss the requirements and methods for satisfying these requirements for motion system, crew station, Instructor Operator Station, Ancillary Equipment and Data Conversion Equipment. Visual system design is not a requirement of this report and assumptions will be made in this area as required to define the visual related requirements of other SMS equipment. The Simulation Computer Complex will be treated as a black box for the most part in this report. The Software Conceptual Design Report will define and evaluate various computer complexes capable of providing the computation power required for the SMS.

The hardware conceptual design effort consists of translating the SMSR training, operational, modification and maintenance requirements into lower level definitions, requirements, and, where possible, actual selection of equipment which will comprise the SMS. As is the case



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in every new simulation task, the majority of the equipment has to be designed for the application from state-of-the-art electrical and mechanical components.

The SMS equipment for the purposes of further discussion will be classified into four major areas (see Figure 1-1), namely,

1. Simulation Computation Complex (SCC) - The SCC will be provided GFP to the SMS and possess the following equipment and capabilities -

- a. Computer Complex & Peripherals - The computer complex will be capable of performing the software required for both crew stations and provide the I/O capability to handle the SMS and time-sharing requirements simultaneously.

- b. Remote/Local Batch Processing Stations & Inter-Active Terminals - A local batch processing station will be provided in Bldg. 5, a remote station in Bldg. 4, and a remote station at an off-site location will be provided. Inter-active terminals will be provided at the same locations.

- c. Digital Conversion Equipment (DCE) - DCE, i.e., mini-computer, DI's, DO's, A/D's, D/A's, will be provided capable of driving the SMS equipment. This report treats the entire DCE as simulation equipment in order to define the total requirements and to examine the feasibility and desirability of other design approaches as the current

dividing line between the SCC and SMS imposes a highly centralized DCE concept on the overall equipment design.

d. Software Capability - Operating simultaneously within the SCC will be the following software.

- i) MBCS Simulation Software
- ii) FBCS Simulation Software
- iii) Time Sharing Software
  - . Data Management System
  - . Batch Processing
- iv) Computer Operating System

2. Motion Base Crew Station Equipment - The MBCS equipment will be delivered initially and will therefore have to be designed to have a completely stand-alone capability. However by considering the overall SMS configuration, economies can be effected by sizing some MBCS components to handle both the requirements of the MBCS and the FBCS. The equipment comprising the MBCS will be classified into the following categories for future discussions:

- a) Crew Station
- b) Forward Visual System
- c) Motion System
- d) Instructor Operator Station
- e) On-Board Computer Equipment
- f) Ancillary Equipment

The MBCS conceptual design will be treated in Section 4.0 of the report.

3. Fixed Base Crew Station Equipment - The FBCS will be delivered subsequent to the MBCS and as discussed earlier, may make use of surplus MBCS capability and also time share some of the MBCS equipment. The equipment comprising the FBCS will be classified into the following categories for future discussions:

- a) Crew Station
- b) Forward Visual
- c) Rear Visual
- d) On-Board Computers
- e) Ancillary Equipment

The FBCS conceptual design will be discussed in Section 5.0 of the report.

4. Shared SMS Equipment - Current equipment candidates for sharing between the FBCS and MBCS are identified on Figure 1-1. However, the final selection of the equipment falling in this area cannot be made until the Baseline Definition Report is finished and as such will only be treated in this report where the particular choice is an obvious cost reduction with no sacrifice in capability.

For brevity of presentation where conceptual designs are the same for the MBCS and the FBCS they will only be discussed in the MBCS.

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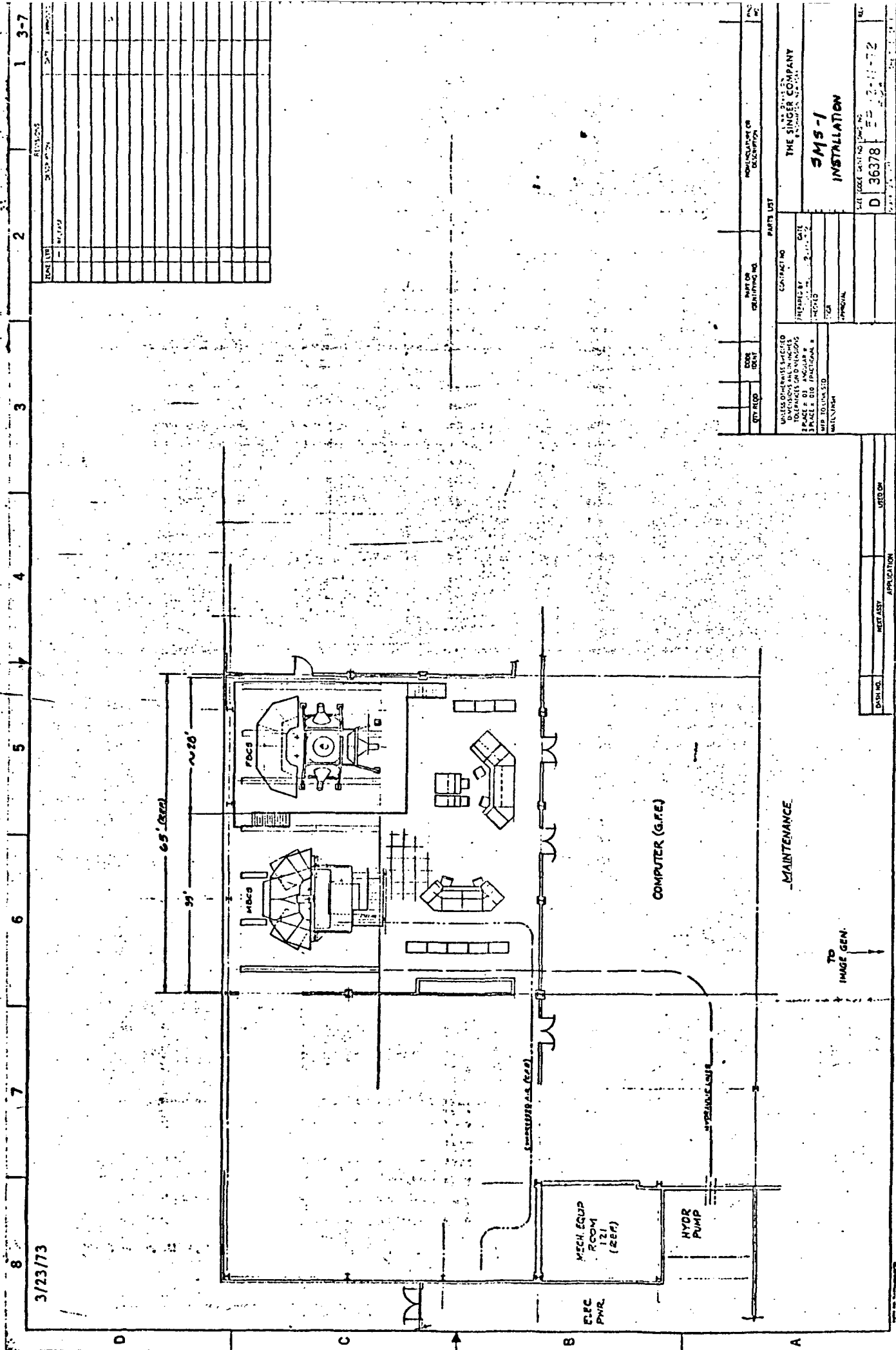
### 3.1 Facility Layout

A viable arrangement at the Houston facility is shown on Fig.

3.1-1 with the Motion Based simulator and Fixed Based simulator both located in the high bay area of the facility which has a 30'-9" high clear ceiling and a concrete floor adequately reinforced to accommodate the relatively high static and dynamic loading imposed by the motion system. Local cable-trough filling and leveling beneath the motion base-plates will be required.

The SMS arrangement as shown on Figure 3.1-1 allows approximately 35 ft. of width for installation of the visual system on the motion platform. The visual system envisioned is comparable in size to that of the ASUPT which required 32 ft. in width during failed motion modes.

The remaining 28 ft of width in the high bay area is devoted to the FBCS raised platform.



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### 3.1.1 Cable Routing

The raised computer flooring will provide space for routing cables between the equipments of the SMS, such as the Digital Computation System, the DCE, Ancillary Cabinets, the Instructor Operator Stations and, when possible, to the Crew Stations.

Cabling will be divided into three electrically and physically separated groups; power, signal, and audio.

All cabling below the computer floor will enter SMS equipment cabinets through the bottom. Cabling to the Motion Base Crew Station will be routed to the centroid location of the crew station/motion system and to the motion electronics cabinets. The cables will be of sufficient length to avoid stress during all excursions of the motion system. Care will be taken to minimize cable movement, and adequate cable protection will be provided.

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#### 4. Motion Based Crew Station Equipment

The equipment requirements of the MBCS are defined in Figure 4-1. The requirements of each major area are as follows:

a) Crew Station - The crew station will be compatible with the motion system and forward visual system and provide the following features:

(i) An active hi-fidelity replica of the Commander and Pilot work stations.

(ii) Aft structure and interior adequate to incorporate the seats for the Mission Specialist and the Payload Specialist.

(iii) Mock-up Aft Work stations to the extent necessary to provide Crew Station realism forward of the Payload/Mission Specialist seat position. Only those controls and displays which are required for flight control need to be active at the aft work stations.

(iv) A removable jump seat IOS.

b) Motion System - The MBCS motion system major requirements are:

(i) Six Degrees of Freedom

(ii) State-of-the-art Synergistic Floor Mounted System

(iii) Redundant Legs

(iv) Cascaded Tilt Axis enabling the Crew Station X-body axis to pitch up beyond 90°.

c) Forward Visual System

(i) Full Field of View Display System



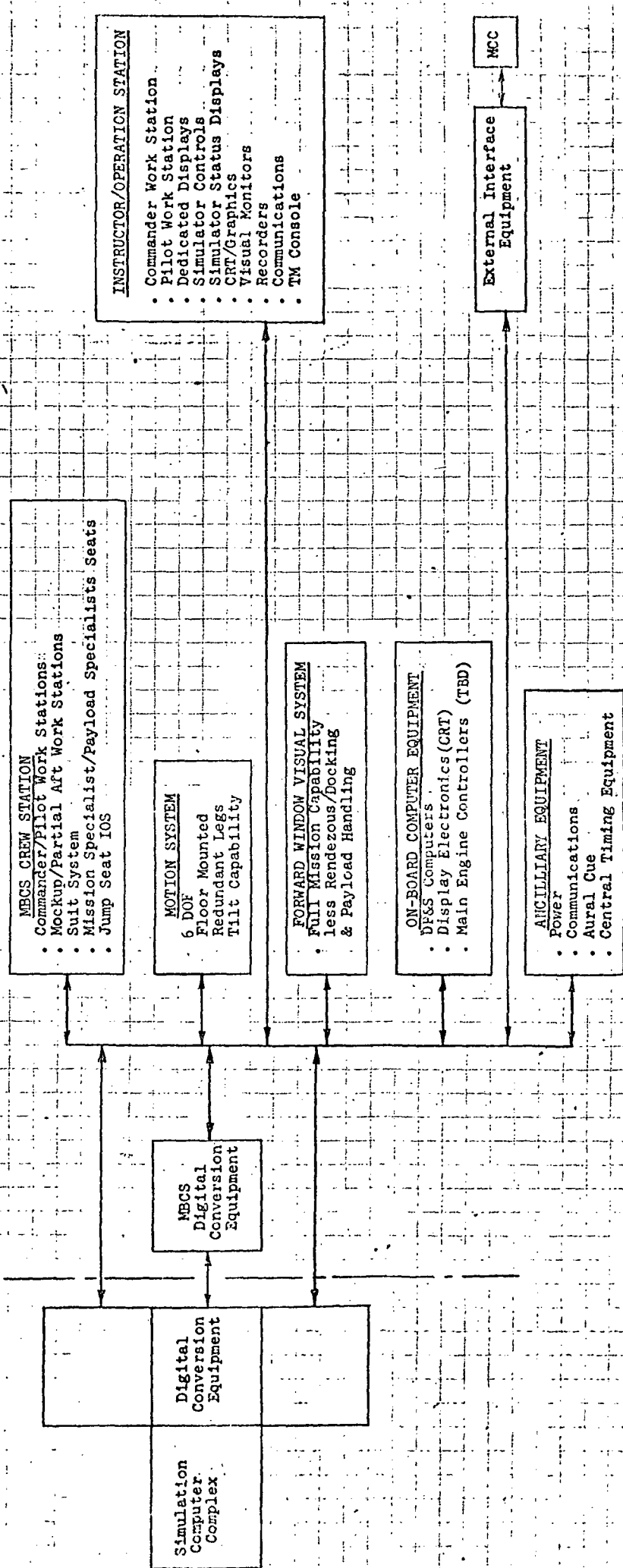


Figure 4.-1

## MOTION BASED CREW STATION EQUIPMENT REQUIREMENTS

(ii) Capable of all scene requirements except Rendezvous, Docking and Payload Operations.

d) On-Board Computer Equipment - This equipment will provide the capability of simulating the vehicle's on-board computers to include:

(i) Data Processing and Software Subsystems

- a) Primary GN&C
- b) Backup GN&C
- c) Auxilliary Processors

(ii) Main Engine Controllers

For the purpose of this report, the simulation shall be capable of handling the redundancy of computers and the resulting switchovers for malfunction situations and the utilization of flight software.

e) Instructor Operator Station - The instructor operator station for the MBCS shall be capable of providing the following capabilities:

- (i) Commander Work Station
- (ii) Pilot Work Station
- (iii) Dedicated Monitoring Displays
- (iv) Simulator Status Displays
- (v) Simulator Controls
- (vi) CRT/Graphic System
- (vii) Visual Monitors
- (viii) Data Recording Equipment
- (ix) Communications Equipment
- (x) Telemetry Console

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The design shall be such as to enable two instructors to accomplish training in the non-integrated mode.

f) External Interface Equipment - Equipment which will enable the MBCS to operate in a closed loop mode with MCC shall be provided.

g) Ancilliary Equipment - Ancilliary equipment requirements fall into a variety of areas namely:

(i) Aural Cue - Equipment shall be provided to duplicate the sound heard within the orbiter vehicle during its missions.

(ii) Power - Equipment shall be provided to enable building power to be converted to the power types and levels required to operate the MBCS equipment.

(iii) Communications - Equipment shall be provided to enable communications between the simulated crew station, IOS, Maintenance areas and MCC.

(iv) Central Timing Equipment - Timing signals shall be provided to enable the MBCS, SCC and MCC to operate in a synchronized manner.

h) MBCS Digital Conversion Equipment - Under the present ground rules the DCE is to be GFP, and as such no unique MBCS DCE requirements are anticipated. However, the overall SMS DCE design is discussed in Section 8.0.

#### 4.1 Motion System

The mission modes requiring motion simulations are launch, launch aborts, re-entry, approach & landing, and the ferry operations. Orbital mission phases are conducted in a zero "g" environment except for brief thrusting maneuvers and therefore will not require motion cues. The motion cues for orbital thrusting maneuvers could be simulated. However, safety precautions would have to be taken to ensure that all crew members are strapped down which may impart negative training. Thus it is envisioned that no motion cues will be provided during orbital flight even though the capability exists. Motion requirements studies have concluded that five degrees of freedom are required for the SMS and that the performance capabilities of most state-of-the-art six degree of freedom motion systems are adequate to provide the motion cues required except for the vertical attitude required for launch and launch aborts. The payload capability required for the SMS is very large, as will be discussed below, and this factor influenced the selection of a six degree of freedom system since the payload capability for state-of-the-art six degree of freedom motion systems is greater than five degree of freedom systems.

During the requirements phase of this study, the Crew Station, Visual System and Motion System interface was identified to be a critical factor in the design of the SMS. As a result, a conceptual design/trade study was conducted which looked at numerous SMS configurations. These studies are documented in the "SMS Training Requirements Report."

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NASA/Singer design reviews and meetings resulted in direction to proceed with the present SMS configuration. The significant conclusion reached was that a complete crew station and visual system with the tilt capability could not be mounted on a contemporary motion system due to payload considerations. The study also concluded that a floor mounted system is more desirable than a suspended system due to the anticipated large size of the visual system and the resulting restriction of angular excursions permissible. As a result, the Singer 48" and 60" stroke was utilized in the analysis since the payload capability of these machines were known and equalled or exceeded the published payload capability of other floor mounted systems. The sixty inch system proved to be better able to handle the anticipated loads and was selected as the recommended motion system. A summary of the analysis performed is described in the following paragraph. Three configurations are examined which bound the spectrum of possible MBCS configurations. The remainder of this section describes the characteristics of the Singer sixty inch synergistic motion system and the modifications required to satisfy the SMS application.

#### 4.1.1 MBCS Configuration Trade-offs

##### 4.1.1.1 Full Forward and Aft Crew Station/Forward and Aft Visual

This configuration defines the optimum fidelity case where the full crew station and visual system are mounted on a motion base. The cascaded tilt capability is limited to 60°. The remaining tilt

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excursion to  $90^{\circ}$  will be provided by the normal pitch capability of the motion system. The configuration and the significant payload characteristics are shown on Figure 4.1.1-1. Assumptions have been made as to the configuration of the visual system in order to permit analysis of the total configuration. Less than full window displays coverage was assumed for the front windows and the rear visual system consists of four windows whereas the current NASA recommended configuration consists of seven windows. Since the assumptions made are less constraining than the current SMS visual system requirements, the conclusions reached are considered valid.

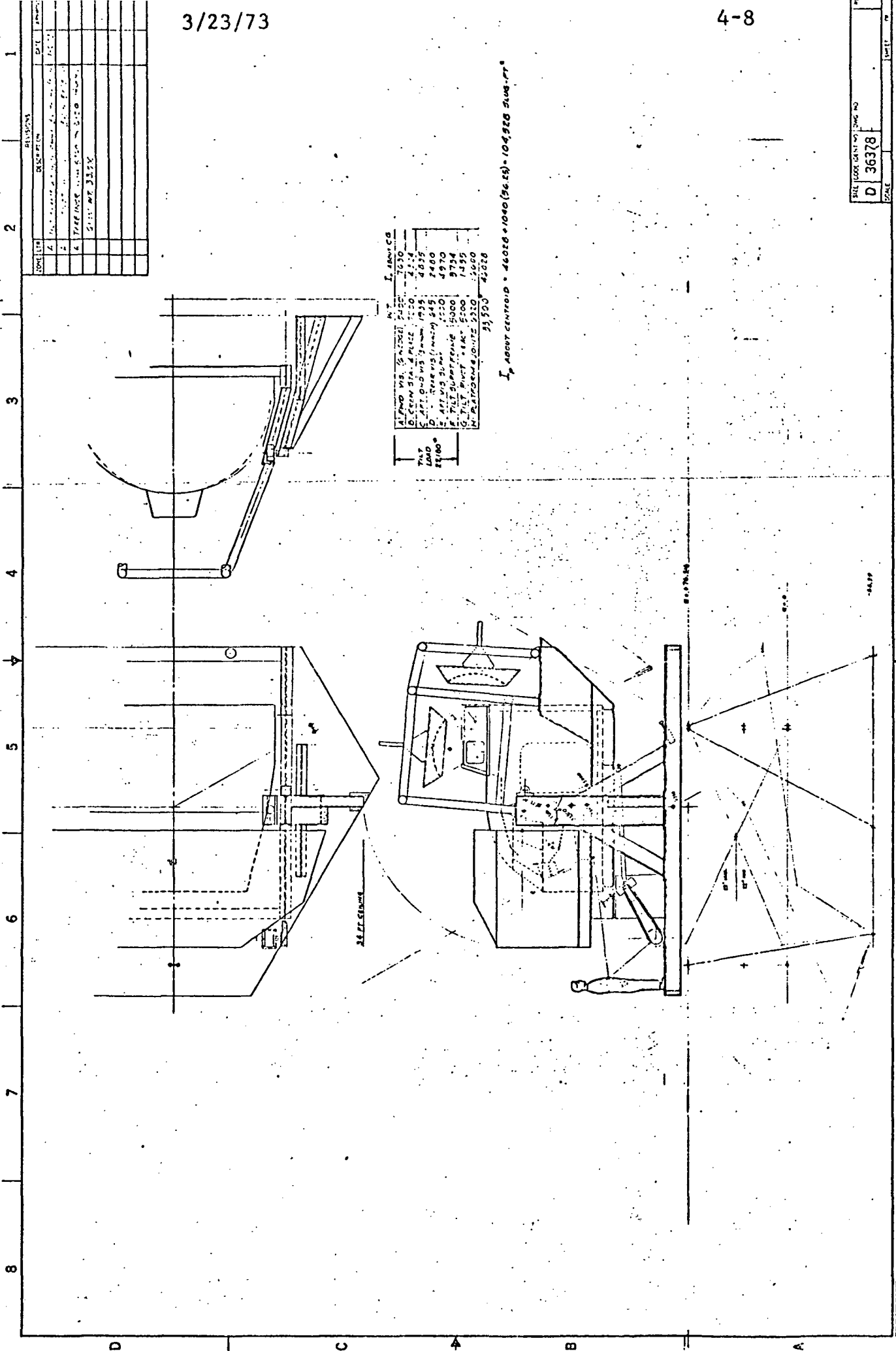
The large aft visual system and support structure overhangs the standard platform sufficiently to warrant designing a new platform and spreading the actuator supporting points to minimize bending. These changes essentially define a new motion system, similar to the sixty inch standard system but with the geometry of the leg attachment points increased to define an 18 ft. equilateral triangle as compared to the 12 ft. equilateral triangle configuration currently used.

This concept results in a gross load of 33,500 lbs. and a moment of inertia in pitch of  $104,528 \text{ slug-ft}^2$ . compared with a certified 23,000 lbs. gross weight and  $37,000 \text{ slug-ft}^2$  moment of inertia for the standard motion systems.

Analytical results indicate an average loading increase of approximately 30% over the maximum loads analyzed with the current

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## FULL FORWARD AND AFT CREW STATION WITH FORWARD AND AFT VISUAL



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payload on the standard motion system. Therefore, a complete analysis, new geometry and revisions to the existing system are warranted. These revisions include reshaping of the deceleration cams, redesigning the relief valve system, increasing the operating pressure, redesigning the lower castings which support the actuator legs, etc. In addition the total weight to be tilted and arrested approximates 22,000 lbs. requiring a complex tilt mechanism. The system seems viable, but considerable development and testing is mandatory. This concept requires a clear ceiling height of approximately 34 ft.

#### 4.1.1.2 Full Forward Cockpit/Front Visual/Jump Seat IOS Configuration

This configuration consists of a crew station, containing the Commander/Pilot work stations, extended aft to Station 505 (reference NR drawing VL70-003047A), far enough to accommodate an instructor/observer seat as close as possible to the Commander/Pilot stations. The same front visual system assumed in the first configuration was used. The configuration and significant payload characteristics are shown in Figure 4.1.1-2. This configuration provides for a  $77^\circ$  tilt capability in addition to the pitch capability of the basic motion system. Either a 48" or 60" motion system is feasible with this configuration. This configuration results in a gross load of 18360# with a moment of inertia in pitch (about the centroid of the upper joint pattern) of  $30,000 \text{ slug-ft}^2$  in the tilted attitude of  $77^\circ$  above



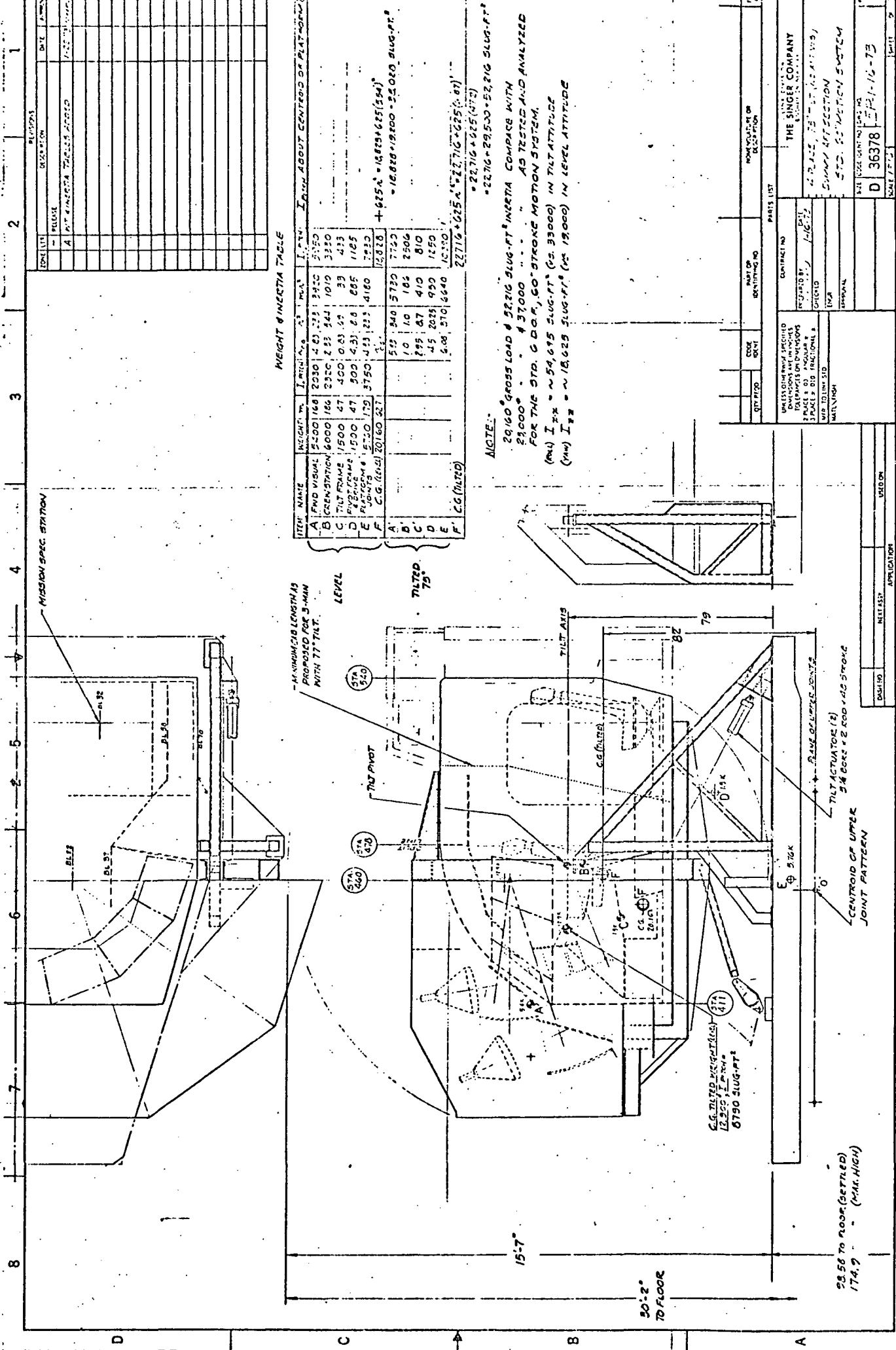


the platform. As such it allows approximately 25% for growth to equal the payload for which the 48" stroke motion system has been tested and documented. It requires a clear ceiling height of approximately 25'-6" on the 48" stroke system.

#### 4.1.1.3 Full Forward Cockpit/Front Visual/Truncated Aft Configuration

As shown on Figure 4.1.1-3 this configuration consists of a crew station which extends aft to Sta. 540 (reference NR drawing VL70-003047A) permitting authentic location of the Mission Specialist and Payload Specialist seats. The stations of these crew members will be simulated to a minimum extent. The only functional indicators and displays will be those associated with aerodynamic flight operations. The forward visual system is the same as assumed in the other configurations. This configuration permits 75 degrees of tilt in addition to the basic motion system. The crew station extension of 35 inches to accommodate authentic aft seat locations requires raising the tilt pivot approximately 36" above the pivot in the configuration of paragraph 4.1.1-2. The estimated gross weight increases to approximately 20,160 lbs. and the moment of inertia in pitch increases to approximately 52,000 slug-ft<sup>2</sup>. This moment of inertia, approximately 40% higher than that for which the motion systems have been tested, renders the 48" stroke motion system less desirable for this concept since the joint and leg loading on the small stroke system is higher than that encountered on the 60" stroke system for the same payload.

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This significantly higher moment of inertia warrants testing of the larger motion system even though analytical calculations indicate loads comparable to those already tested and operational.

#### 4.1.1.4 Recommended Configuration

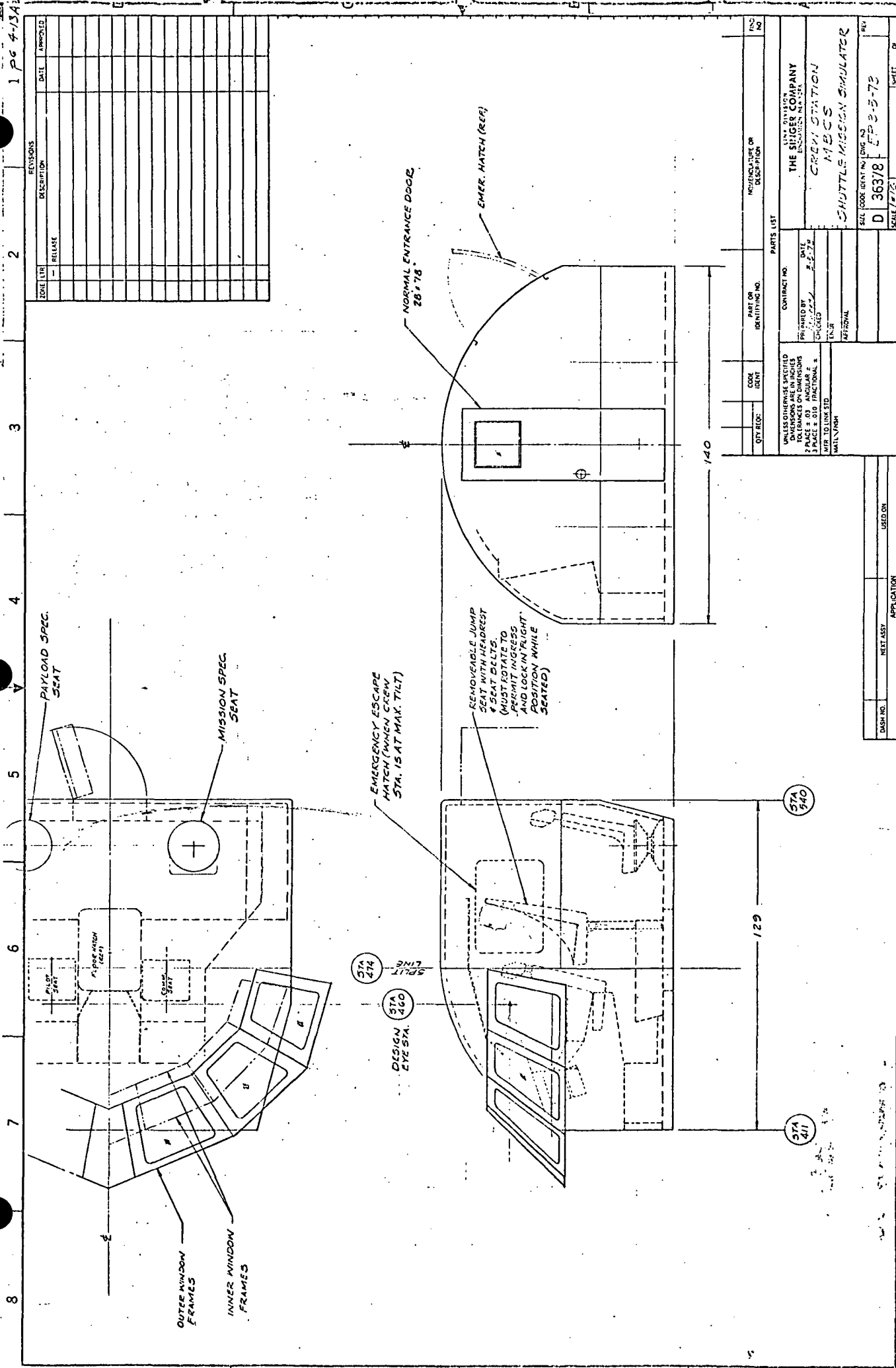
The recommended configuration concept is that described in paragraph 4.1.1.3, with the full-fidelity forward crew stations, a full forward visual, and an aft section sufficiently large to accommodate the aft crew members in their authentic seating locations. This payload will be mounted on a tilting frame permitting  $75^{\circ}$  of positive pitch from the tilt mechanism alone. Refer to Figure 4.4.1-4.

This payload will be mounted on a 60 inch stroke standard motion system with potentially modest changes desired due to the increased moment of inertia. In addition, a redundant leg system is recommended to enhance the safety of the basic system and add redundancy to the deceleration devices of the basic system.

A removeable instructor/operator station will also be required which will be centered in and as close as possible to the C/P center console.

Any relief on the aft seating requirements which permits shortening the crew compartment will be desirable since it would

- 1) reduce the total load and enhance the growth capability
- 2) lower the tilt pivot location and thus relieve the loads on the tilt structure and the total moments of inertia.



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FIG. 4.1.1-4

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3) reduce the required ceiling height which is a function of the height of the tilt pivot. The resulting configuration would then approach that described in paragraph 4.1.1-2.

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#### 4.1.2 Singer 60" Six Degree of Freedom Motion System

A description of the capabilities of the Singer 60" Motion System and its application and modifications required for MBCS use will be described in the following sections.

The Singer six-degree-of-freedom motion system (Figure 4.1.2-1) provides independent motion in six degrees of freedom. This capability is achieved by simultaneous operation of six linear hydraulic actuators arranged in three bipod pairs, as shown in Figure 4.1.2-2. The hydraulic system driving the actuators has sufficient power and capacity to provide appropriate positional and acceleration cues while supporting payloads specified herein.

The six-degree-of-freedom motion system is synergistic. That is, the activation of all six hydraulic actuators is generally required for motion in any degree of freedom. The 60-inch stroke motion system was successfully utilized on various 747, DC-10, and L-1011 simulators and NASA research projects, and is shown in Figure 4.1.2-3.

The following sections describe the motion system capabilities, operation, safety features, and mechanical and hydraulic design features.

##### 4.1.2.1 Mechanical Configuration

The basic mechanical configuration of the motion system is shown in Figure 4.1.2-2. The basic system consists of six independent hydraulic servo actuators, each controlled by a three-way servo valve.

The actuators are arranged in pairs to form bipods at the floor frame. The piston rod ends of each of the actuators attach to



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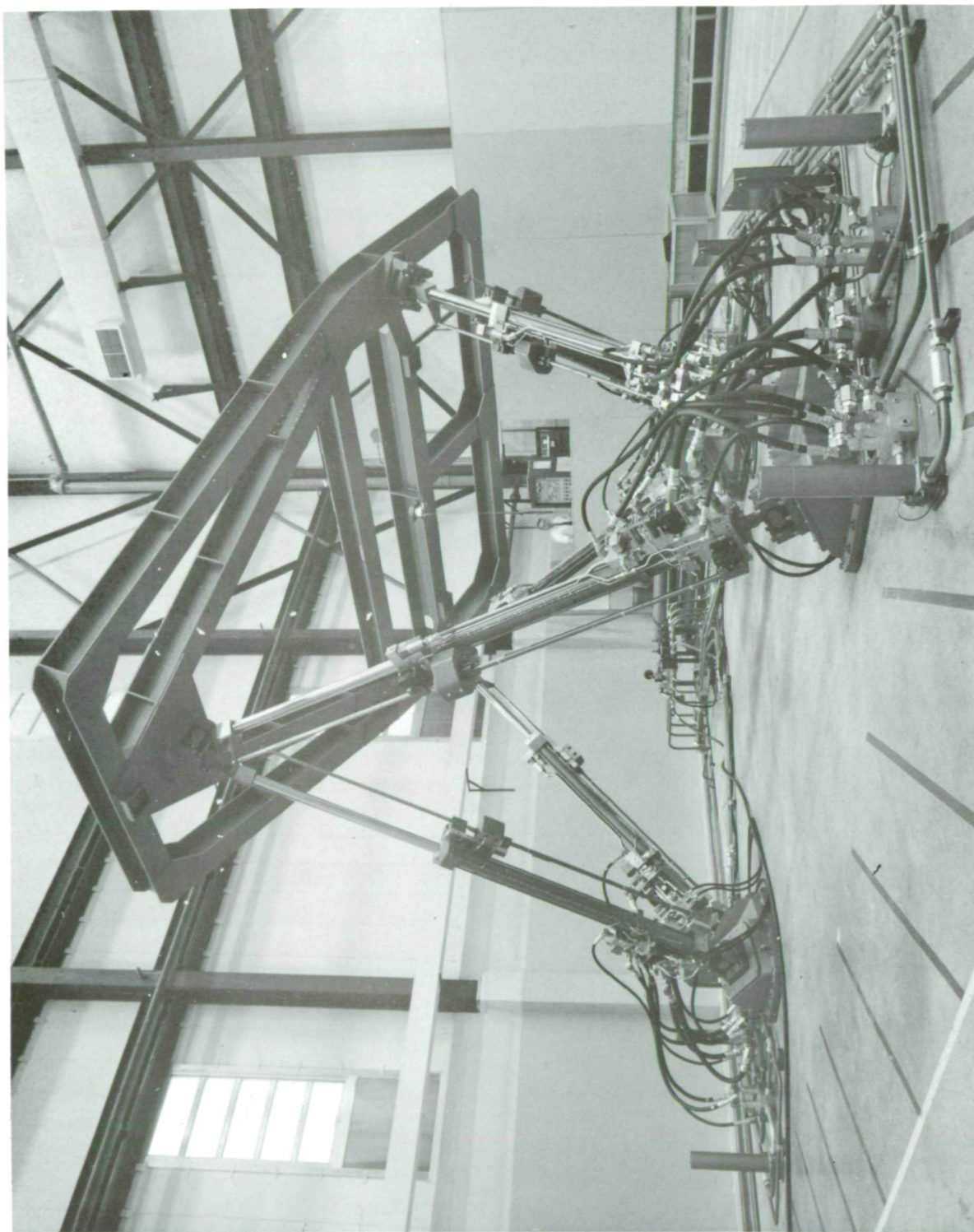


Figure 4.1.2-1 SINGER 60" SIX-DEGREE-OF-FREEDOM MOTION SYSTEM



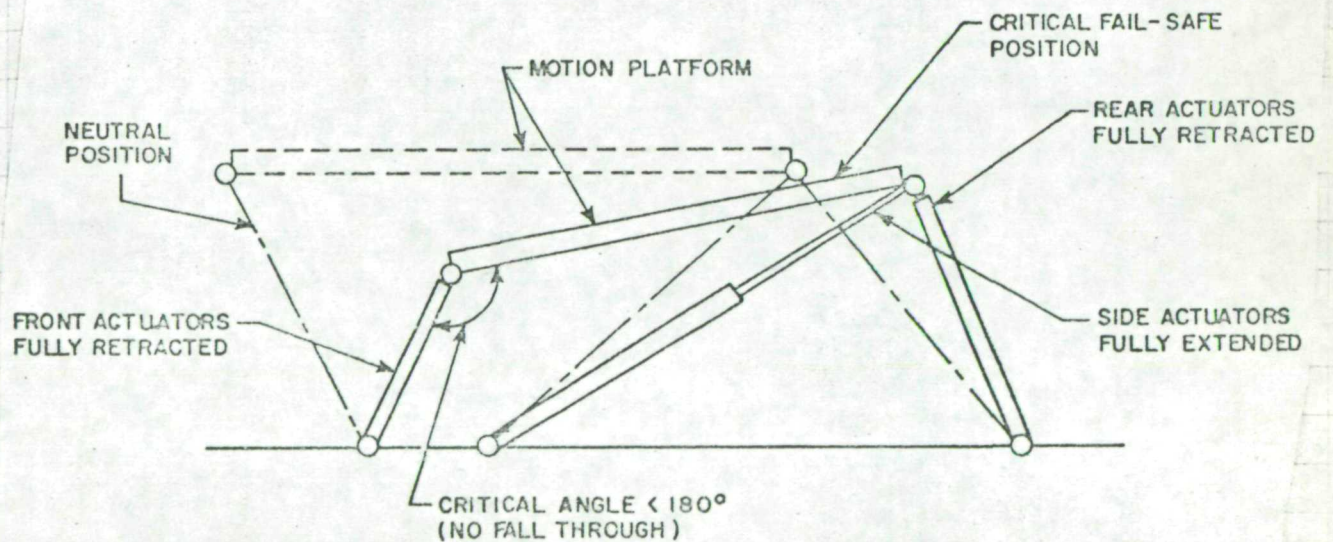
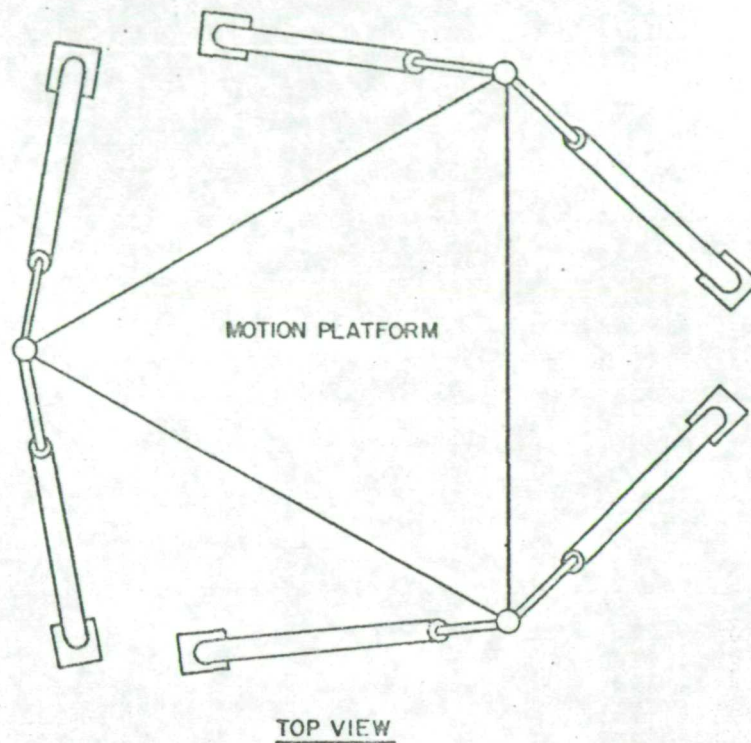


Figure 4.1-2-2 MOTION SYSTEM BIPOD CONFIGURATION (FAIL-SAFE)

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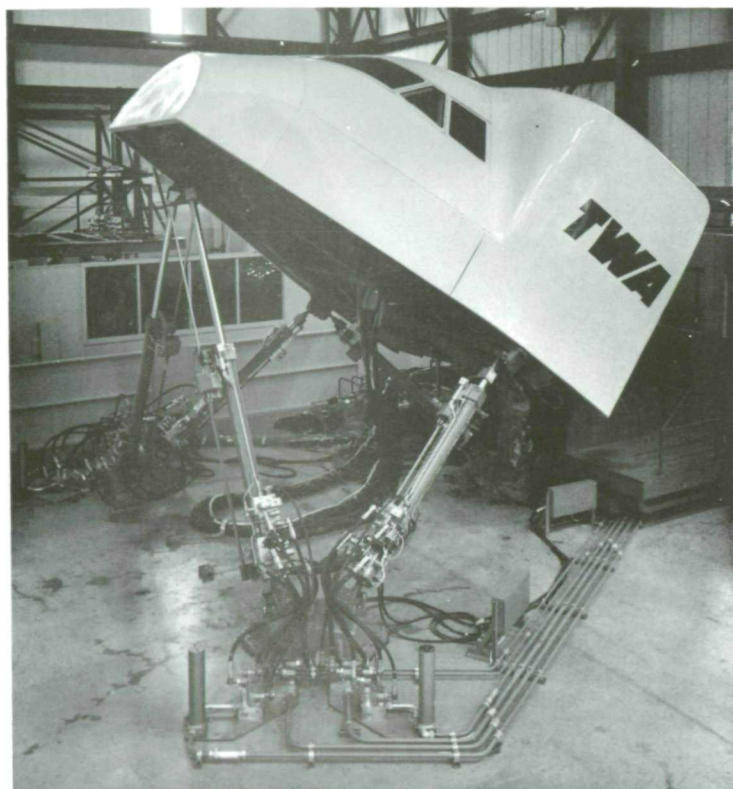


Figure 4.1.2-3 TWA 747 SIMULATOR SHOWING  
SIX-DEGREE MOTION SYSTEM

a ball-joint-type universal fitting on the frame. This joint is shown in Figure 4.1.2-4. Two actuators attach to each of the three universal fitting assemblies. The bottom end of each actuator attaches through a two-rotational-degree-of-freedom gimbal fitting assembly to the floor. This joint is shown in Figure 4.1.2-5.

#### 4.1.2.2 Fail-Safe Configuration

The mechanical fail-safe aspect of the design is also illustrated in Figure 4.1.2-2, which shows a plan and two side elevations of the floor-mounted actuators and the motion platform. The motion system in its neutral position is shown in the side view by the broken-line drawing. The solid-line drawing shows the motion system in an orientation in which the rear actuators are fully retracted, the side actuators are fully extended, and the front actuators are fully retracted. The basic principle demonstrated is that by canting the plane of the bipods, the relative angles between each bipod and the motion platform can be restricted, thereby preventing fall-through and reducing the maximum loads imposed on the actuators. The configuration has been optimized to allow maximum excursions with a minimum of power. Figure 4.1.2-6 also presents a plan and side views of the motion system, and shows the motion platform position with the actuators fully retracted (the "settled" position), at approximately mid-travel (the "neutral" position), and fully extended.

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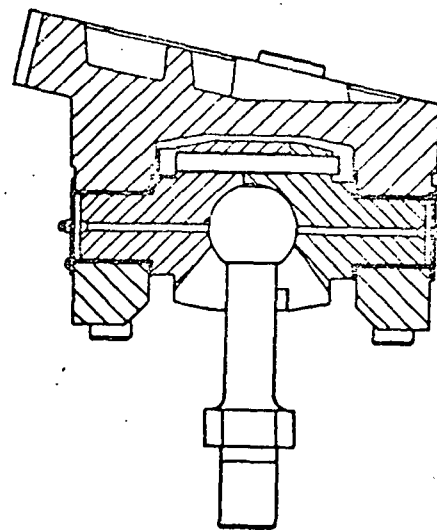
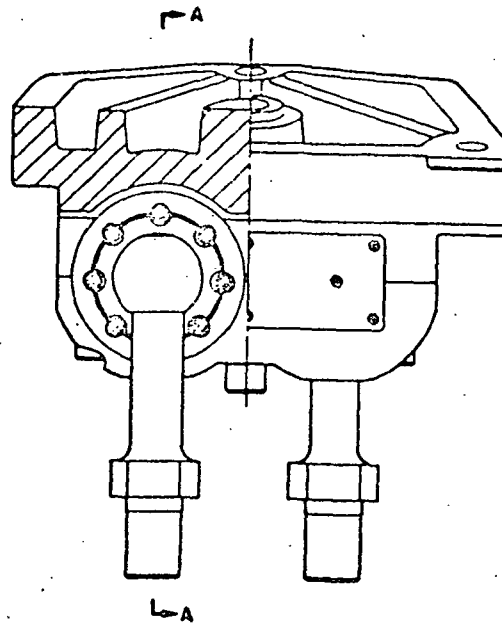


Figure 4.1.2-4 - UPPER BALL-TYPE  
UNIVERSAL JOINT



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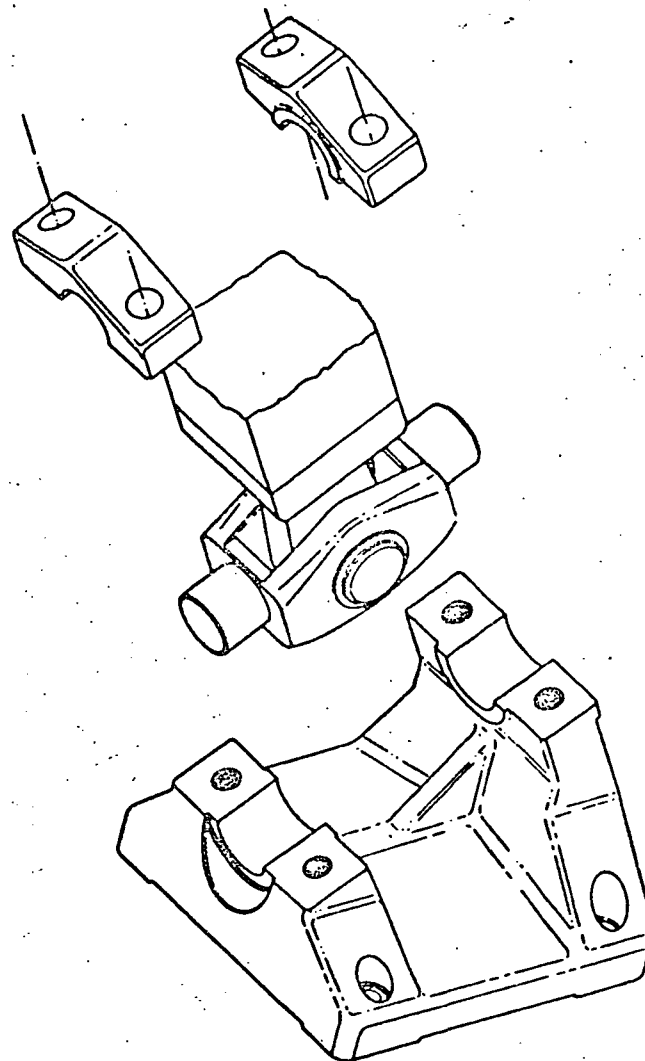


Figure 4.1.2-5 LOWER GIMBAL-  
TYPE JOINT

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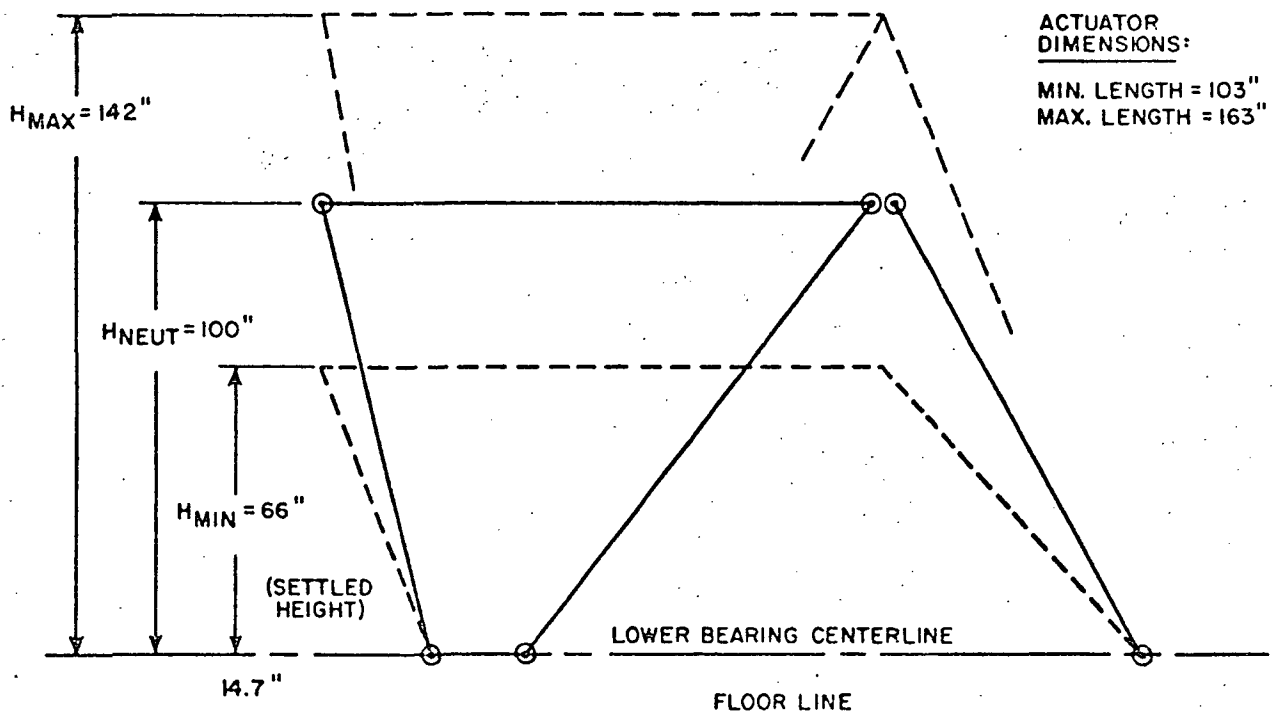
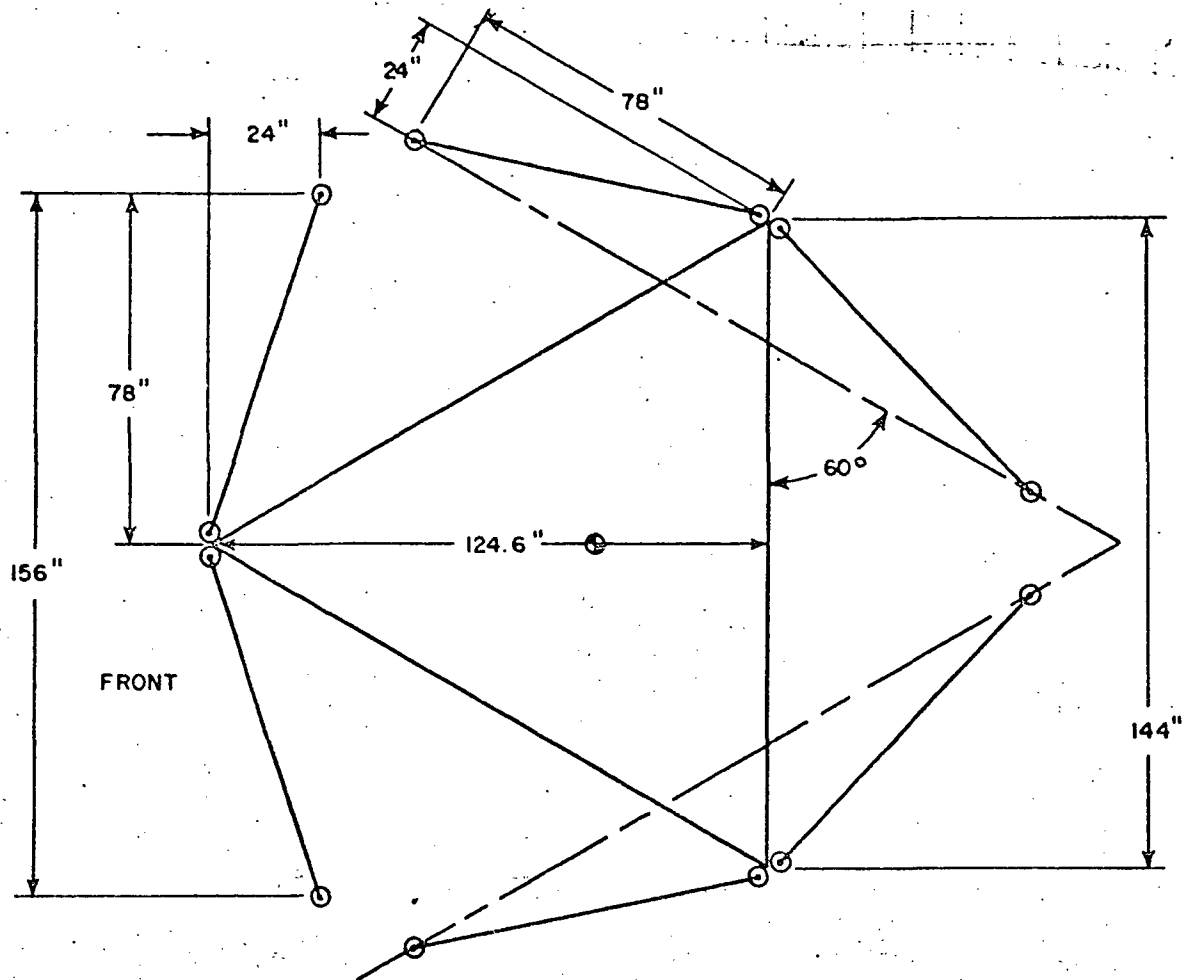


FIGURE 4.1.2-6  
MOTION SYSTEM IN NEUTRAL, SETTLED, AND RAISED POSITIONS

#### 4.1.2.3 Motion System Capabilities

The normal limits of performance of the motion system in each degree of freedom, operating from the normal "neutral" position, are as follows (all values measured at the motion platform):

##### 1) Pitch

- a) Rotation: \* +30, -20 degrees
- b) Velocity:  $\pm 15$  degrees/second
- c) Acceleration:  $\pm 50$  degrees/second/second

\* With a shift of the centroid position it is possible to obtain pitch angles of  $+34\frac{1}{2}^{\circ}$  and  $-30^{\circ}$  within operational limits of the actuators.

##### 2) Roll

- a) Rotation:  $\pm 22$  degrees
- b) Velocity:  $\pm 15$  degrees/second
- c) Acceleration:  $\pm 50$  degrees/second/second

##### 3) Yaw

- a) Rotation:  $\pm 32$  degrees
- b) Velocity:  $\pm 15$  degrees/second
- c) Acceleration:  $\pm 50$  degrees/second/second

##### 4) Vertical

- a) Translation: up to 39 inches, down 30 inches
- b) Velocity:  $\pm 24$  inches/second
- c) Acceleration:  $\pm 0.9$  g

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5) Lateral

- a) Translation: 48 inches right and left
- b) Velocity:  $\pm 24$  inches/second
- c) Acceleration:  $\pm 0.6$  g

6) Longitudinal

- a) Translation: Forward 48, aft 48 inches
- b) Velocity:  $\pm 24$  inches/second
- c) Acceleration:  $\pm 0.6$  g

These figures reflect the maximum programmed values for normal operation with a payload of 23,000 lbs., with the C.G. approximately 62" above and  $6\frac{1}{2}$ " aft of the centroid of the upper joint patterns, and inertial loads about the centroid of:

$$I_{xx} = 33,000 \text{ slug-feet}^2$$

$$I_{yy} = 37,000 \text{ slug-feet}^2$$

$$I_{zz} = 19,000 \text{ slug-feet}^2$$

The listed performance is well within the motion system capability in both velocity and acceleration.

The simultaneous capabilities of the motion system may be defined in an infinite number of ways, since the system has the ability to trade off motion capabilities from one degree of freedom to another.

4.1.2.4 SMS Loading and Weights

The motion based SMS payload is estimated at 20,160 lbs. with a C.G. (in the tilted attitude) approximately  $82\frac{1}{2}$ " above and  $6\frac{1}{2}$ " aft



of the centroid. The new moments of inertia about the centroid are approximately as follows:

$$I_{xx} = 54,695 \text{ slug-feet}^2$$

$$I_{yy} = 52,216 \text{ slug-feet}^2$$

$$I_{zz} = 18,625 \text{ slug-feet}^2$$

A static and dynamic analysis was performed for 2 of the severe attitudes possible for the 6 D.O.F. 60" stroke motion system for the design load anticipated for the SMS. For comparison purposes these leg loads are tabulated below against the same severe attitudes for a 48" system with the standard maximum design loads. The leg components (except for the length of the actuators) are identified on the 48" and 60" system, and the 48" system due to its geometry will experience higher loads than the 60" system.

	<u>Std.Des.Load</u>	<u>SMS</u>	<u>DLH on 48" System</u>
Weight	23,000#	20,160#	
I (about centroid)	37,000 slug ft <sup>2</sup>	52,500 slug ft <sup>2</sup>	
<u>C.G. Location</u>			
Above centroid	62"	82½"	
Aft of centroid	6½"	6½"	
<u>Actuator Loads</u>			
Fwd Toggle Pos.			
Fwd Legs (true static)	9.38K	9.68K	9.4K
Fwd Legs (true dyn.)	5.41K	7.8K	
Aft Legs (true static) 5.1K (tension)		5.7K (T)	6.0K
Aft Legs (true dyn.)	13K (T)	14.7K (T)	
Aft Toggle Pos.			
Aft Legs (true static)	13.9K	12.8K	16.36K
Aft Legs (true dyn.)	14.6K	15.2K	

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Thus the differences of loading appear insignificant for these analyzed attitudes, and any changes found necessary would be to optimize performance and decelerations to preclude damage to the visual systems.

The SMS payload weights and loads were developed in the following manner.

Motion System Payload (pounds):

Cockpit and Cables	5,200
Personnel (4)	800
Visual Display	<u>5,400</u>
Total Payload	11,400

Total Weight on the Floor(pounds):

Payload	11,400
Tilt Frames & Mechanism	3,000
Tare (platform, upper joints and actuators)	5,760
Lower Actuators (6)	1,980
Base Assembly (3)	6,000
Redundant Leg Assemblies	5,100
Hydraulic Lines	<u>3,000</u>
Total Floor Weight	36,240

Worst-Case Dynamic Load (pounds)

Because of Maximum Acceleration  
Capability of Motion:

Compression	46,000
Tension	30,000
Shear	31,000

Maximum dynamic loads do not occur on every pad at any given instance. Values given are for the most heavily loaded pad. (The area of each floor pad is 5,000 square inches.)

#### 4.1.25 Motion System Performance

Depending on the particular flight program, the motion system is capable of responding to computer input signals as noted in the following examples.

##### 4.1.2.5.1 Ground Conditions

The motion system is capable of providing the indications appropriate to motion of the aircraft on apron, taxiway, and runway. The motion will be a random, low-frequency, low-amplitude, multi-directional oscillation with reasonably abrupt application. The computations could enable varying the amplitude of oscillation to reproduce the irregularities of unimproved or unprepared surfaces. The system will reproduce the longitudinal effects due to abrupt brake applications, rejected takeoffs and the lateral effects due to asymmetric braking, asymmetric thrust, or loss of directional control on icy runways.

##### 4.1.2.5.2 Takeoff and Landing

During the takeoff roll, the ground performance of the motion system will be as described in the previous subsection. Transition to flight will be indicated by abrupt cessation of the random oscillation. The motion system will provide the correct indications of takeoff rotation and will maintain a nose-up attitude appropriate to the climb-out.

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Appropriate longitudinal effects will occur as a result of changes in thrust, retraction of landing gear, and retraction of high-lift devices. Similar effects will be reproduced during the landing phase, where gear extension and lift and drag-inducing extension will cause appropriate longitudinal, vertical, and low-frequency vibration effects to occur in the motion system. The motion system will correctly reproduce the landing impact according to the existing aircraft attitude and vertical and sideslip velocities and, where the vertical momentum is greater than the absorption capabilities of the shock absorbers, landing bounce will be simulated.

Pitching and rolling effects of single truck contacts will be correctly reproduced, and the magnitude of the bounce will be dependent on the current landing weight. The longitudinal and pitching effects of brake application will be correctly simulated. Mishandling of the brakes during rollout under poor runway conditions will cause lateral effects associated with skidding where appropriate.

For an aborted landing, the motion simulated will be similar to a normal landing in the initial stages, followed by rotation, increase in thrust, and climbing associated with takeoff simulation.

The longitudinal motion and ground effects associated with effective braking and deceleration will be simulated for an aborted takeoff.

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The effects of thrust, altitude, and attitude changes in a missed approach will also be simulated. The motion system will be capable of simulating the more complex combinations of motion cues associated with the circling approach and landing maneuver.

#### 4.1.2.5.3 Normal Flight

A thorough exercise of the motion system capabilities will be necessary to simulate the complex and repeated cues occurring during airwork maneuvering. By virtue of the capability of the motion system to move in six degrees of freedom, and to provide cues correct in direction and proportional in magnitude to the Orbiter acceleration, all the maneuvers associated with airwork will be simulated correctly.

The introduction of varying degrees of turbulence will produce the appropriate motion effects of severe pitch and roll, rapid climb or descent, and above-placard speed.

Superimposed upon the background motion, the motion system will provide the characteristic periodic oscillations of the Orbiter such as the phugoid oscillation, short-period oscillations, and lateral instability, and will also simulate characteristic Orbiter vibrations up to 5 cycles per second.

#### 4.1.2.5.4 Abnormal Flight

The motion system will be capable of correctly reproducing the effects of the stall, such as stall buffet (up to 5 cycles per second), pitch down, and wing droop under asymmetric conditions.

The lateral motion and roll effects of an engine failure, during takeoff and normal flight, will be simulated, including the adverse effect of momentary incorrect rudder input, as well as conditions appropriate to yaw damper, autopilot, Mach trim failure, or hydraulic failure resulting in asymmetric control configurations. High-speed characteristics, such as Mach buffet and trim changes, will cause appropriate effects in the motion system.

#### 4.1.2.6 Actuator Servo Control Loop

The motion system hydraulic actuator is connected in a regenerative-type hydraulic system configuration. The rod side of the actuator is connected directly to the hydraulic power supply, and flow to or from the ram side of the actuator is controlled by a three-way servo valve.

In order to provide the most realistic simulation of motion cues, a rapid, smooth, nonhunting response to all input signals is desirable. This is assured with the control system design by the tightly compensated servo-loop used in the hydraulic system. Further, the design ensures that the overall system resonant frequency is large compared with both normal operating and buffet frequencies, and thus avoids the possibility of exciting resonance with higher frequency components of servo-control input signals. The normal operating bandwidth is sufficiently wide to be compatible with the bandwidth of servo-control input signals.

#### 4.1.2.7 Motion System Hydraulics (See Section 4.1.2.11)

In order to determine the hydraulic flow requirements, several duty cycles representative of worst-case maneuvers were defined. The hydraulic pumps were sized to provide full average flow required for these maneuvers, with peak demands supplied from accumulators. These accumulators are recharged during that part of the maneuver when actuator flow demand is below pump capacity, enabling the system to respond without performance degradation. This can be achieved with two 60-gpm pumps, as illustrated in Figure 4.1.2-7

#### 4.1.2.8 Motion System Controls

##### 4.1.2.8.1 Ingress and Egress

For boarding purposes, the motion system is deactivated using controls described in Section 4.1.2.8.2. The motion system then returns smoothly to the settled position, shown in Figure 4.1.2-6 and the access platform can be raised to allow entrance to or exit from the flight compartment.

Note that the return to the "settled" or "at rest" static position is the eventual result of electrical or hydraulic shutdown at any time because the design configuration maintains compressive loads in all actuators. The inherent stability of the motion system thus obviates the necessity for external means of forcing normal return to the settled position or providing locking devices for maintaining the position.

#### 4.1.2.8.2 Activation and Deactivation

The motion system deactivation logic circuitry ensures that the motion system comes to rest in a full-down "at rest" position. A master maintenance control, located on the electronics cabinet, is provided to ensure that the motion system is always deactivated when maintenance personnel are inside the motion structure.

#### 4.1.2.8.3 Emergency Deactivation

Activation of the "emergency stop" switch, at the maintenance panel, results in complete shutdown of the entire system and, as such, is only used for rapid deactivation of the motion system (in preference to the normal deactivation controls) under extreme conditions. In this case, a command is provided to a quick-settle control valve for returning the motion system to the settle position from any attitude at the highest practicable speed. The quick emergency settle rate of the cylinder piston is approximately 4 inches per second. The normal rate is approximately 3 inches per second. The access platform rises to meet the motion system under the power of a reserve stored energy source. The design allows all personnel to safely egress to the service platform in 24 to 31 seconds, depending on the position of the cockpit at the time electrical power is cut off.

#### 4.1.2.9 Safety Features

In addition to the activation and deactivation interlock features described in Section 4.1.2.8.2 and the quick-settle control



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described in Section 4.1.2.8.3, the following design features are incorporated with a view to increasing the safety aspects of the motion system.

Suitable protective devices are installed to protect personnel and equipment - i.e., to prevent bottoming of actuators because of the control valve inadvertently being driven to an end stop, and upon initial turn-on of the system (surge protection). Mechanical stops and independent dual electrical limit switches (See Section 4.1.2.9.1) are included in the motion system. Should a runaway type of failure occur, a shutdown feature automatically switches off the power to the motion system and returns the platform to the "at rest" position at a smooth controlled rate.

A loss in hydraulic pressure causes a shutdown of the system whether the pressure loss is intentional or accidental. Tracking error of significant magnitude between commanded and actual position is detected and an automatic shutdown is initiated. In the event of a malfunction of any reference power source, all circuits, power and servo-control, are suitably interlocked to terminate motion by a complete system shutdown.

The following devices and techniques provide for the safe operation of the motion system.

#### 4.1.2.9.1 Limit Sensing

Limit switches are provided to sense travel of the actuators beyond the servo electronic limits. Two sets of limit switches on each

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servo actuator are provided: one set provides velocity attenuation in the event of a runaway servo; the other set provides for a complete shutdown of the motion system. In this situation, the motion system returns to its "at rest" position at a smoothly controlled rate.

#### 4.1.2.9.2 Velocity Control

In addition to the velocity attenuation noted in 4.1.2.9.1, both internal flow control and external cylinder piston velocity buffer controls are provided to mechanically control both maximum velocity and the rate of piston deceleration if all other safety features fail. The buffers are cam-operated-type deceleration valves, actuated by a rod driven from the piston rod, and provide a controlled rate of change of piston speed as the actuator piston approaches its end of stroke.

Relief valves are provided to limit the maximum force that may be generated by the actuator and are the fast-acting mechanical/hydraulic sensing type. These relief valves are on the servo actuator to provide complete protection regardless of actuator position.

Slow-turn-on hydraulic valving is provided to preclude shocks from being transmitted during motion turn-on (surge control) and turn-off.

#### 4.1.2.9.3 Crush Pads

Maximum dynamic load protection is provided through the utilization of a special, honeycom-pad device incorporated in the lower joint assembly. The shock pad is captivated and implemented in a manner

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to provide for both tensile and compressive loading protection.

Lower joint assembly floor pads are designed to limit floor loading to a value under 100 psi for the worst-case dynamic loading. This value of loading allows the use of normal-mix reinforced concrete as used throughout the construction industry. The worst-case dynamic loads are transient loads, generally present only during the period when the motion system is undergoing a maximum acceleration and generally sustained for a period of 30 milliseconds or less.

The base pads are designed to be lagged to a concrete floor using commercially available lag inserts.

#### 4.1.2.9.4 Universal Joints (See Figure 4.1.2-4 and 4.1.2-5)

To provide structural integrity and safety in the design of the motion actuator attachments, universal joints are utilized at each end of the actuator. These joints are designed for a minimum yield strength factor of 4.0 times the maximum dynamic load factor which can be encountered at the joint by the operation of the motion system. The breaking strength of this joint provides for an ultimate safety factor of 6.0. The maximum dynamic load is calculated on the basis of a complete failure of all safety systems used in the motion system.

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Compressive loading of the joints under maximum programmed acceleration of the motion system provides for a safety factor of 7.7 times the minimum yield strength. This factor, combined with the use of high-film-strength lubrication on the sliding parts of the joints, ensures maximum reliability and longevity of performance of the joints.

#### 4.1.2.9.5 Hydraulic Actuators

Special design consideration is devoted to providing for maximum strength and reliability of the hydraulic actuator. Bearing loads and cylinder design insure maximum service life of the cylinder. The column strength of the actuator is such as to provide a minimum safety factor of 4 for the critical buckling load. A special rod seal leakage collector is provided to scavenge hydraulic leakage past the piston rod seal.

The load-carrying capability of the actuators is dependent upon both the static load requirements of positioning the cockpit system to its extremes of motion and the maximum acceleration capability of the actuator when positioned very close to its maximum extended length. It is at this position that the column strength of the actuator is the least. A minimum safety factor of 4 relative to this extreme situation has been provided in the design.

During operation of the motion system near its normal neutral position (at a 20-inch extension of the actuators), the safety factor for the column strength at worst maximum loading is 8.9.

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It is anticipated that the motion system will operate at or near the neutral position during 90% of its operating time. The normal maximum accelerations anticipated provide for a safety factor of 15.9 with all safety systems operational. The high safety factor in this region provides for maximum reliability, endurance, and maintenance-free operation of the actuators.

Consideration is given to the side loading at the piston rod bearing. This side loading results because of the cant of the actuator. The force vector normal to the bearing is dependent upon the static component of the actuator weight and its angle with the vertical, plus the dynamic transients that could be present because of failure-type step inputs from the computer. The maximum worst-case side load that can be experienced in the maximum failure mode at cant angle results in a bearing pressure of less than 70 psi. The controlled leakage past the piston rod seals also ensures good lubrication of the bearing. This lubrication and the low side loading of the actuator bearing ensure long life and maintenance-free operation of the actuators.

#### 4.1.2.9.6 Support Structure

Design of the motion system load-carrying support structure provides for a minimum safety factor of 4.0 times the yield strength of the materials used in the construction, based on the maximum dynamic load that may be encountered during the operation if all safety systems fail.

#### 4.1.2.10 Maintenance Provisions

Ease of maintenance was a prime consideration in the design and construction of the motion system. For example, system transducers provide voltage outputs directly without the need of demodulators. Hydraulic fluid level indicators are clearly visible and system replenishment is easily accomplished. There are adequate provisions for bleeding lubricating the system.

The hydraulic control panel shown in Figure 4.1.2-8 is provided as part of the hydraulic power system, with provisions for semi-automatic troubleshooting of the hydraulic power control system. This feature, which is implemented by the use of color-coded readout lights for strategic parts of the system, provide a go/no-go type of indication, thereby pinpointing the area of system malfunction. The panel is also provided with gauges to provide a continuous indication of the operation of the hydraulic system at all times.

Two cylinder change jacks are also provided along with jack receptacles on the motion platform to assist in changing a motion actuator assembly. The purpose of these jacks is to enable the load to be taken off the cylinder by support of the payload.

The Motion System Electronics Cabinet is of modular panel-type construction. The standard cabinet includes the Power Distribution Control Panel (Figure 4.1.2-9), the Motion System Maintenance Control Panel (Figure 4.1.2-10), the Cylinder Position Control Panel (Figure 4.1.2-11),

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and the Test Points Panel (Figure 4.1.2-12).

The Power Panel provides the  $\pm 24$  VDC and +28 VDC power for the motion system. Circuit breaker protection for the input and output power is provided as well as switches for ON/OFF power control.

The Maintenance and Cylinder Position Control Panels are provided in the Motion System Electronics Cabinet for ease of maintenance and troubleshooting. They are equipped with controls and indicators for manual operation of the system, thereby isolating the computer inputs. The intention of this feature is to allow each servo to be checked operationally without removing the servos from the system or to allow operation of the system entirely through manual or analog means of control - i.e., off-line.

The Test Point Panel provides easily accessible test points of critical signals associated with each servo actuator.

#### 4.1.2.11 Hydraulic System

The hydraulic pump used to provide hydraulic power for the motion system is of the variable-displacement type and is remotely located in order to reduce noise level. At maximum displacement, the pumps provide a sufficient amount of fluid to meet circuit demands. The maximum pump pressure is at least 1.5 times the maximum working pressure of the system. The hydraulic system operates at 2,000 psi.

The hydraulic system block diagram is shown in Figure 4.1.2-7.

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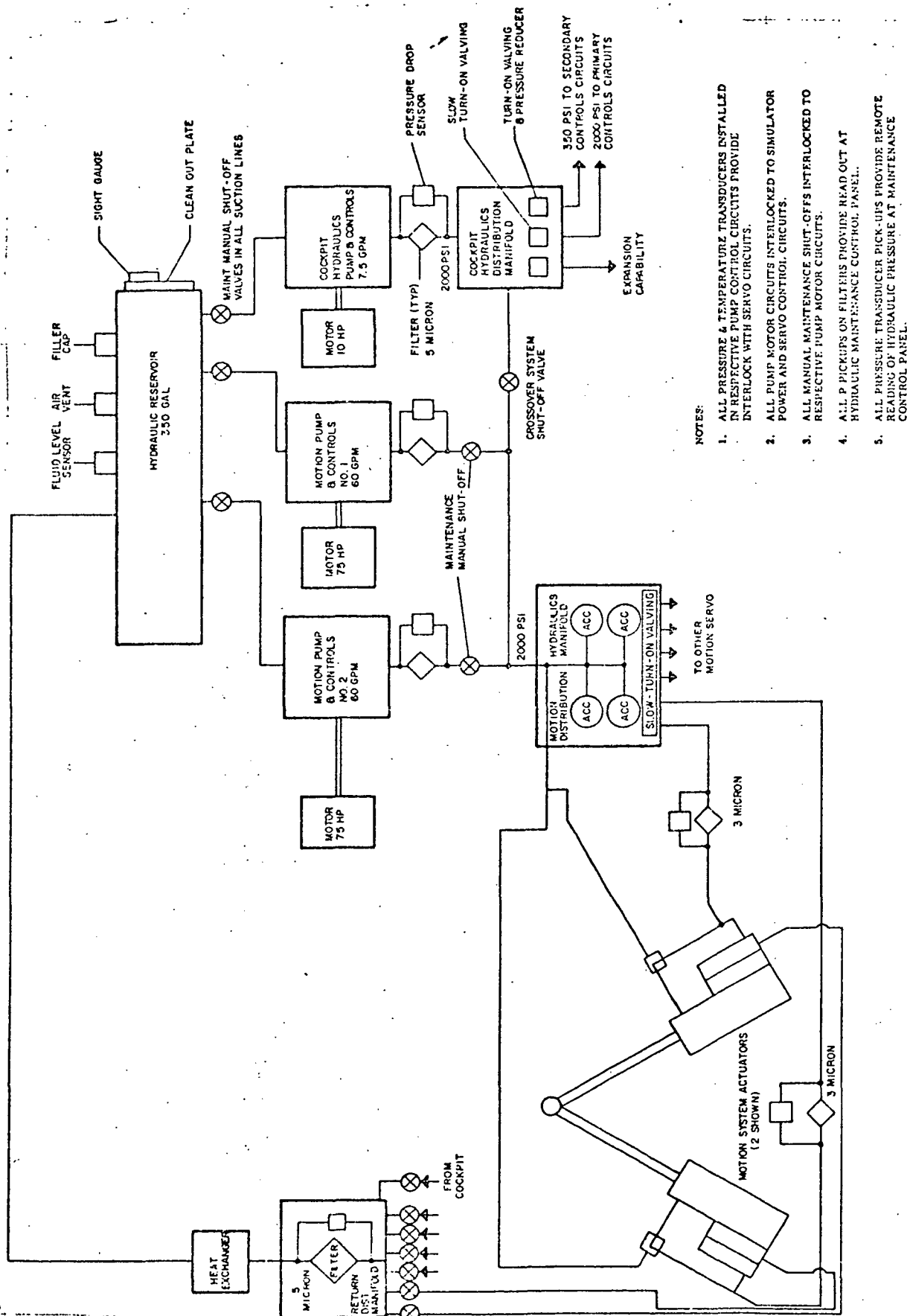
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## NOTES:

1. ALL PRESSURE & TEMPERATURE TRANSDUCERS INSTALLED IN RESPECTIVE PUMP CONTROL CIRCUITS PROVIDE INTERLOCK WITH SERVO CIRCUITS.
2. ALL PUMP MOTOR CIRCUITS INTERLOCKED TO SIMULATOR POWER AND SERVO CONTROL CIRCUITS.
3. ALL MANUAL MAINTENANCE SHUT-OFFS INTERLOCKED TO RESPECTIVE PUMP MOTOR CIRCUITS.
4. ALL P. PICKUPS ON FILTERS PROVIDE READ OUT AT HYDRAULIC MAINTENANCE CONTROL PANEL.
5. ALL PRESSURE TRANSDUCER PICK-UPS PROVIDE REMOTE READING OF HYDRAULIC PRESSURE AT MAINTENANCE CONTROL PANEL.
6. COCKPIT HYDRAULIC POWER MAY BE OBTAINED FROM MOTION CIRCUITS BY ACTIVATING CROSS OVER SYSTEM VALVE.

Figure 4.1.2-7

MOTION SYSTEM HYDRAULICS



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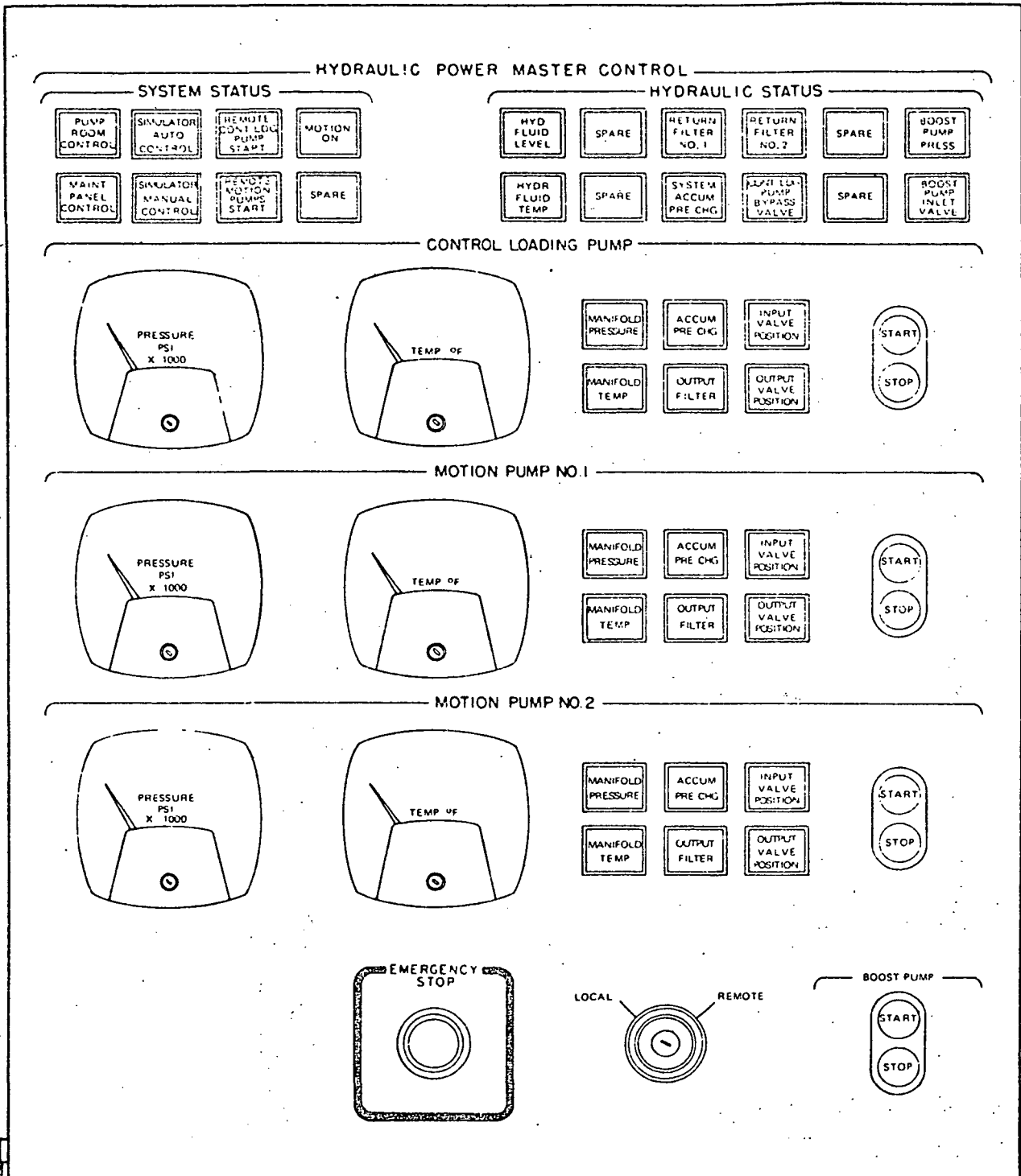
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SPEAKER AND  
MICROPHONE  
JACKS

Figure 4.1.2-8

HYDRAULIC POWER SYSTEM MASTER CONTROL PANEL

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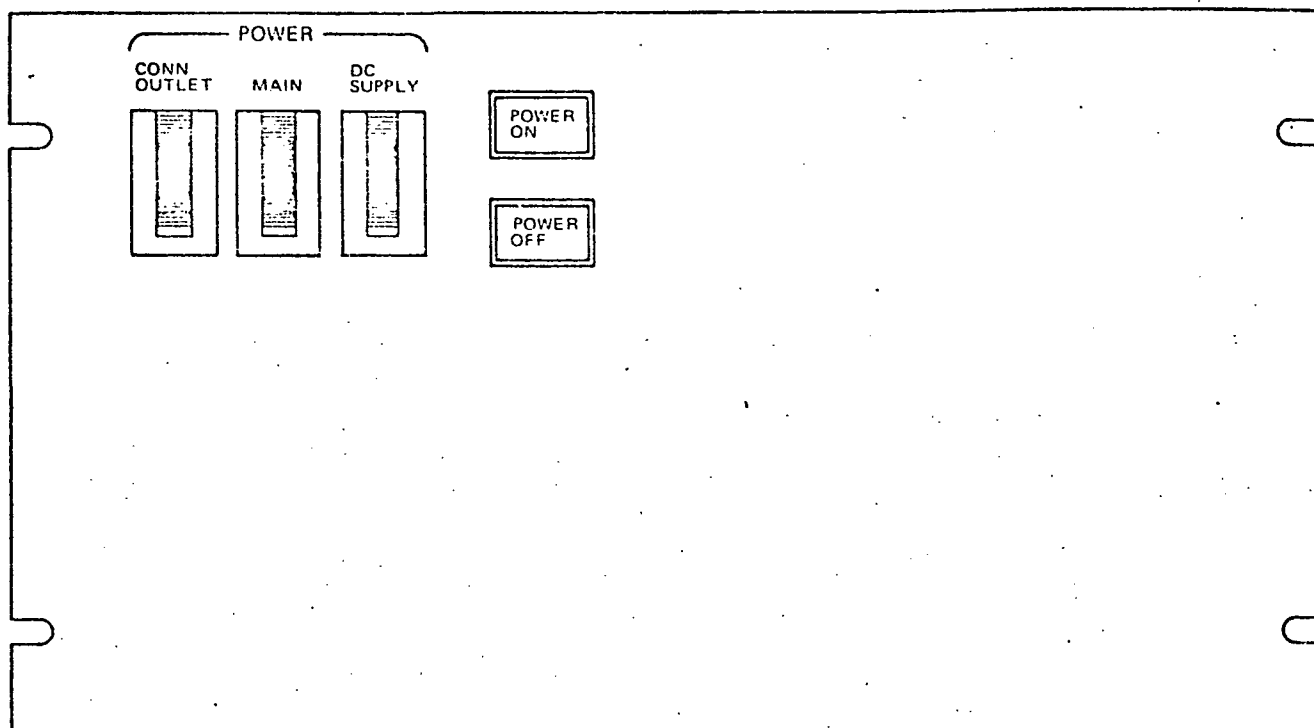
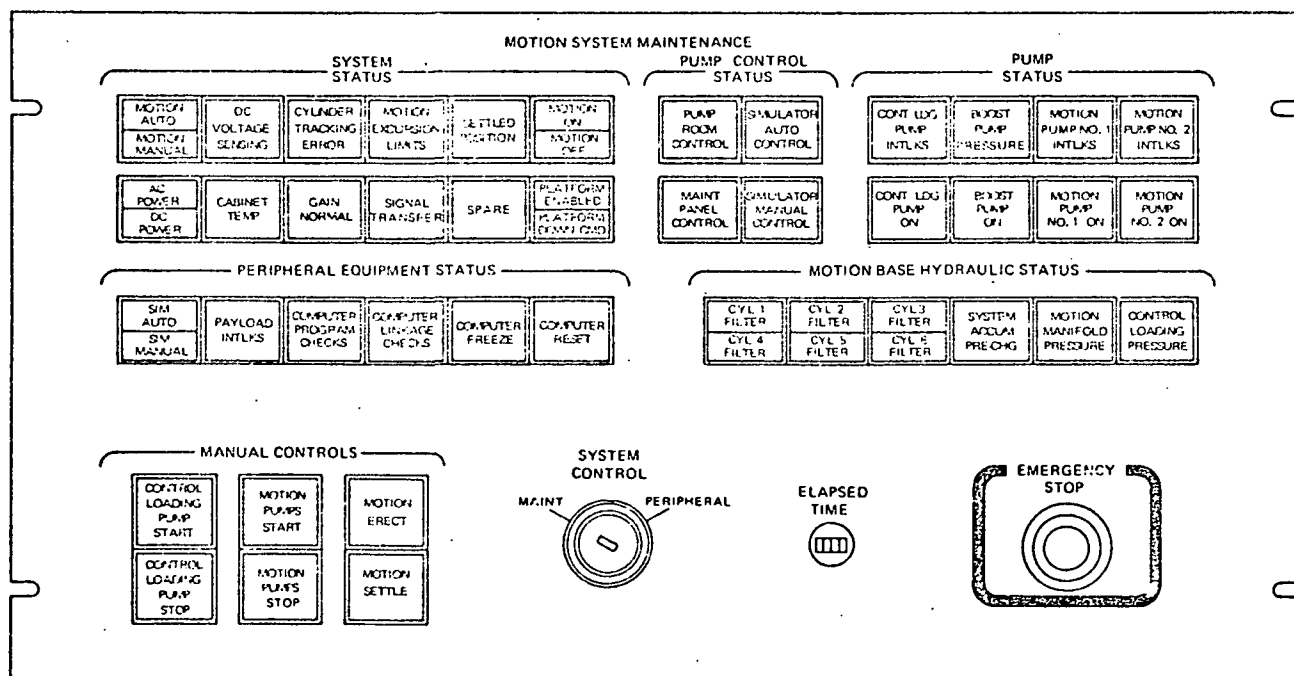
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FIGURE 4.1.2-9  
POWER DISTRIBUTION CONTROL PANELFIGURE 4.1.2-10  
MOTION SYSTEM MAINTENANCE CONTROL PANEL

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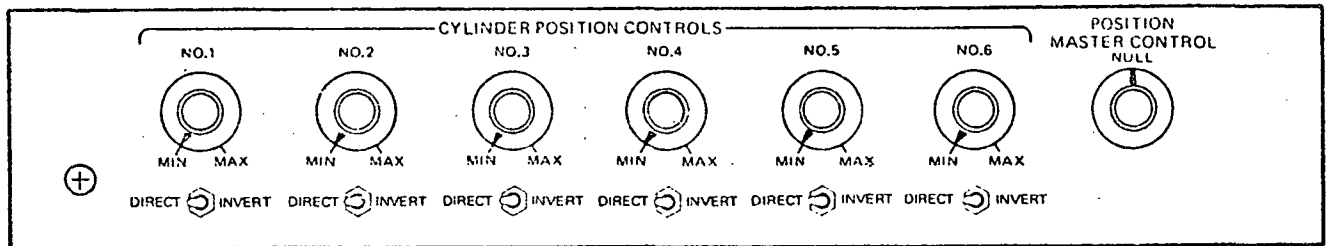
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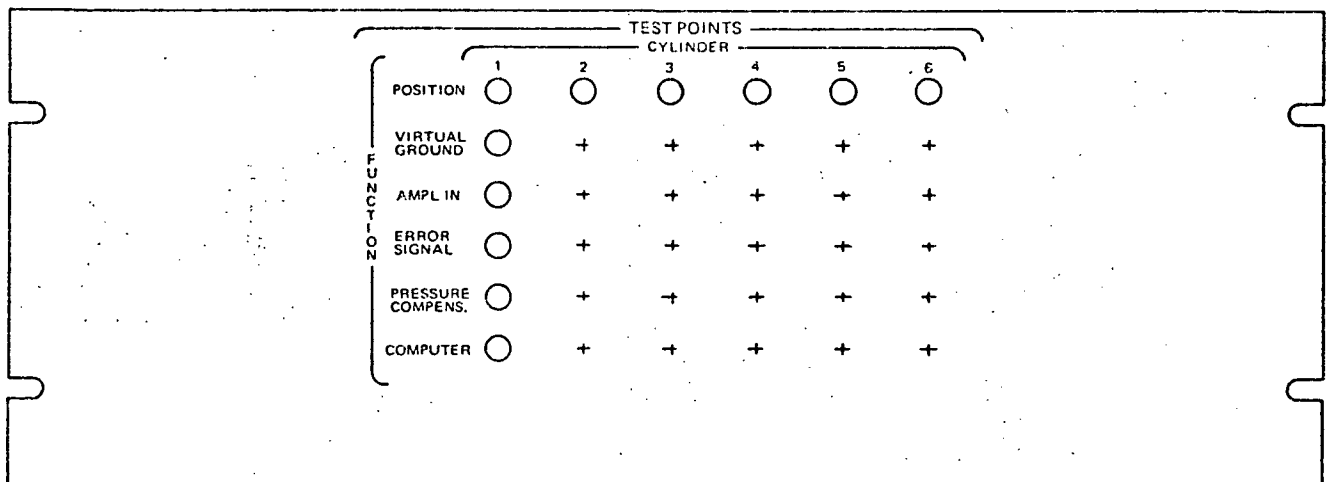
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FIGURE 4.1.2-11

CYLINDER POSITION CONTROL PANEL



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Figure 4.1.2-12

TEST POINTS PANEL

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The pumping system main pressure line is provided with a pressure gauge to indicate system pressure and an oil temperature gauge and automatic oil temperature monitoring system which shuts the pump down if the oil temperature exceeds a preset value. Accumulators of adequate capacity are used to compensate for line loss; a gas pressure gauge is provided with each accumulator. The hydraulic reservoir is of adequate capacity and is provided with a visual-type contents gauge and a device that automatically shuts down the system when the fluid level falls below a predetermined safe level. The reservoir is provided with a filtered air vent. Adequate provision is made for filling, draining, and cleaning the reservoir. A high-capacity filter of 3 microns nominal rating is installed in the return line to the reservoir. High-pressure filters of 3 microns nominal rating are installed immediately upstream of each servo valve. All fluid filters are provided with pressure-drop warning lights to indicate element contamination level. A pressure relief valve is provided and functions when the maximum operating pressure is exceeded by 100 psi. All pressure and temperature gauges and controls are mounted on a panel in the pump room. All connections to the panel are flexible to reduce vibration on the panel.

Steel tubing is used throughout the system except where moving components dictate flexible hoses. Adequate interlocks are provided for pressure loss, over-temperature, and excess flow protection.

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Pressure, temperature, quantity, and accumulator gauge readings are available and instrumented at the hydraulic control panel located centrally within the pump room. All hydraulic filter warning lights are displayed at the control panels. Complete control of the pump system is possible from the control panel at the hydraulic unit. A key-operated master maintenance switch is provided at the control panel in the pump room, which isolates the pump motor circuits for maintenance. An independent maintenance interphone system provides communication between the pump room, computer room, and motion system area.

#### 4.1.2.12 Installation Requirements

##### 4.1.2.12.1 Motion System Room

The MBCS will be installed in Bldg. No. 5 of the Manned Spacecraft Center at Houston as shown on Figure 3.2-1.

The motion system will be installed on the 8 inch thick reinforced concrete floor at the north end of the building. The room is approximately 63 ft. wide x 60 ft. long with a 30 ft. high ceiling extending approximately 32 ft. from the north wall. This space must accommodate the MBCS, the FBCS, the I/O Station and the cabinets desirably located close to the crew station.

The motion system must be positioned to insure clearance of the payload for all possible attitudes of the motion platform. This will require filling of some of the existing cable trenches in the floor and filling some areas now occupied by computer flooring to accommodate installation of the entrance platform.

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4.1.2.12.2 Hydraulic Power Room Arrangement

The room at the West end of the building is allocated for the Electrical and Hydraulic Power. This room must accommodate the Hydraulic Power for 3 motion systems, the HFTS and (2) SMS motion based simulators. A proposed arrangement of the required components for this room is shown on Figure 4.1.2-13. A trench must be made in the floor and a hole cut through the wall to accommodate the routing of hydraulic lines to the MBCS, approximately 140 ft. distant.

The following will be required to accomodate this system.

1) 460-volt, three-phase, four-wire delta power supply capable of meeting at least the following demands:

<u>Equipment</u>	<u>Starting Power (kva)</u>	<u>Running Power (kva)</u>
Main Pump No. 1 (75 hp)	109	70
Main Pump No. 2 (75 hp)	109	70
Boost Pump (5 hp)	34	4
Control Loading Unit (10 hp)	64	9



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2) Water source capable of delivering at least 15 gallons per minute of water at a minimum pressure of 40 psi with a maximum inlet temperature of 85°F.

#### 4.1.2.13 Redundant Legs

The motion system will include the redundant leg system.

This consists of 6 additional hydraulic actuators placed generally parallel to and inside of the geometry defined by the servoed actuators. They are shown on Figure 4.1.2-14.

They are affixed to the platform and castings on the floor plates in a manner similar to that of the servoed actuators.

These six identical actuators are self-contained hydraulic "springs" exerting a lifting force on the platform as a result of the pressure in a five gallon accumulator attached to each leg. With accumulator pressure set at 200 psi (settled position) these legs exert a heave force of approximately 6300# in settled position and approximately 4290# at maximum high position.

Each piston is designed with tapered fittings which cushion the last 5 inches of stroke in each direction thus decelerating the motion and limiting the shock imposed upon the system and payload.

In addition to this redundant cushioning feature the legs will support the payload in the unlikely event of breakage of a servoed leg or its components.



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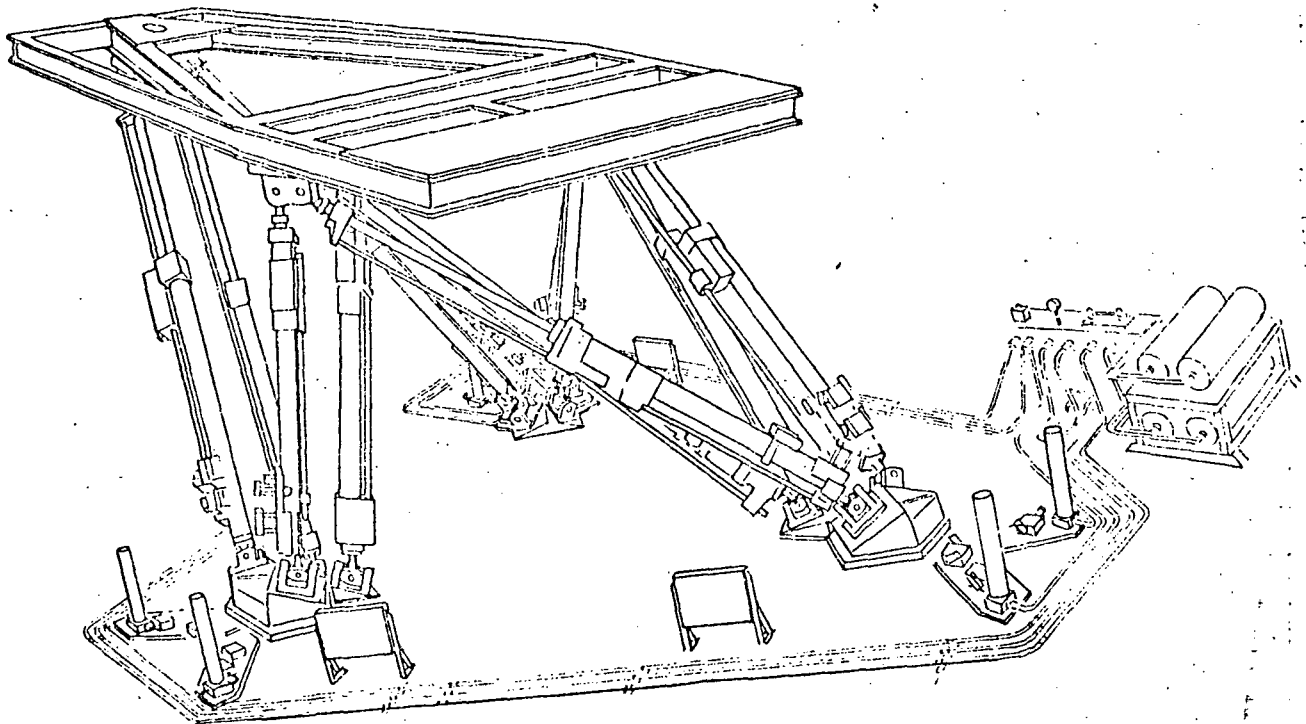


FIGURE 4.1.2-14

SIX-DEGREE-OF-FREEDOM MOTION SYSTEM  
WITH REDUNDANT LEGS

#### 4.1.2.14 Tilt Mechanism

A tilt mechanism is cascaded on the motion platform to provide  $+75^{\circ}$  of positive pitch angle to the crew station, visual system and tilt frame independent of the pitch capability of the motion system. The estimated load to be tilted is approximately 12,900 lbs. (The motion system can add an additional maximum operational pitch of approximately  $34^{\circ}$  for a total positive pitch of  $109^{\circ}$ ).

The tilt mechanism consists of a tilt frame, tilt pivot support frame, drive mechanism, lateral stabilizing mechanism, and the outrigger frames to support the pivots in a lateral axis as shown on Figure 4.1.2-15.

The tilt frame is a welded platform on which the forward visual system and cockpit can be mounted, and a large arch which surrounds the crew station in a vertical plane providing upper attachment points for the visual system and cockpit. It also contains the structure for the pivot axis.

The tilt frame will be constructed of aluminum alloy structural shapes, sectionalized as necessary to facilitate handling and shipping.

The tilt pivot support frames will be fabricated of welded aluminum tubing, with a split bearing housing welded at the top, 79" above the platform. The frames will be trussed in both directions and the motion platform will be extended laterally to provide support in a lateral direction. These frames will be bolted to the edge of the platform on each side.

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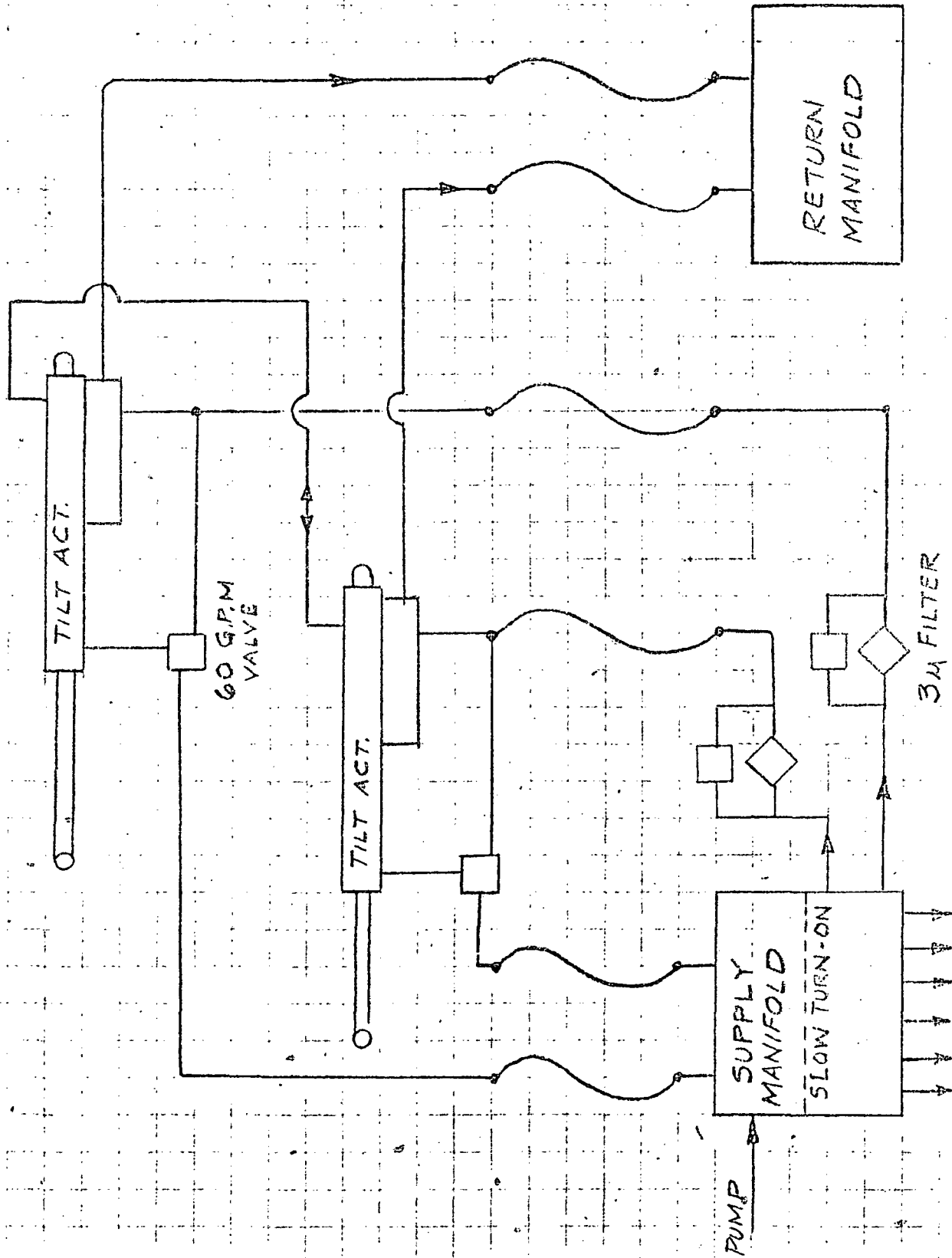


FIG. 4.1.2-15 - HYDRAULIC SCHEMATIC - TILT MECHANISM

A hydraulic actuator, 3½" bore x 2" rod x 48" stroke with cushioned stroke at each end, will be installed on the outboard side of each pivot frame and attached to a clevis on the tilt frame on each side. These actuators will be servoed to control the attitude and rate of tilt. At both maximum tilt and minimum tilt they will hold the payload steady with full system pressure applied to the actuators.

Lateral motion will be constrained by a scissors type linkage attached to the underside of the tilt frame and to the motion platform. A redundant lateral restraint will be accomplished with rub plates mounted on the lower edge of the aft tilt frame which are in contact with mating plates on the pivot frame near the platform surface. These two precautions will limit the side load carried at the tilt pivots and relieve the bending on the pivot frame and the platform extension framework.

The platform extension will be compatible with and bolted to the standard motion platform, extending approximately 2 feet beyond the existing platform profile on each side.

Hydraulic power for the tilt actuators will be supplied from the existing hydraulic distribution manifold.

#### 4.1.2.15 Entrance Ramp

The aft portion of the flight compartment will be surrounded by a fenced walkway attached to the motion platform. Access to the walkway will be provided by means of a hydraulically powered stairway (see

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Figure 4.1.2-16) that will automatically rise to the level of the walkway with the platform in the settled position whenever the motion system is deactivated. A separate accumulator will supply power to the stairway actuator in the event of failure of normal hydraulic or electrical power. An interlock will preclude activation of the motion system when the stairway is not fully down in the stowed (horizontal) position. The stairway will be mounted parallel to the rear edge of the motion platform in the settled position, lagged to the concrete subfloor. It will be equipped with tubular safety railing and nonskid (open mesh) stair treads.

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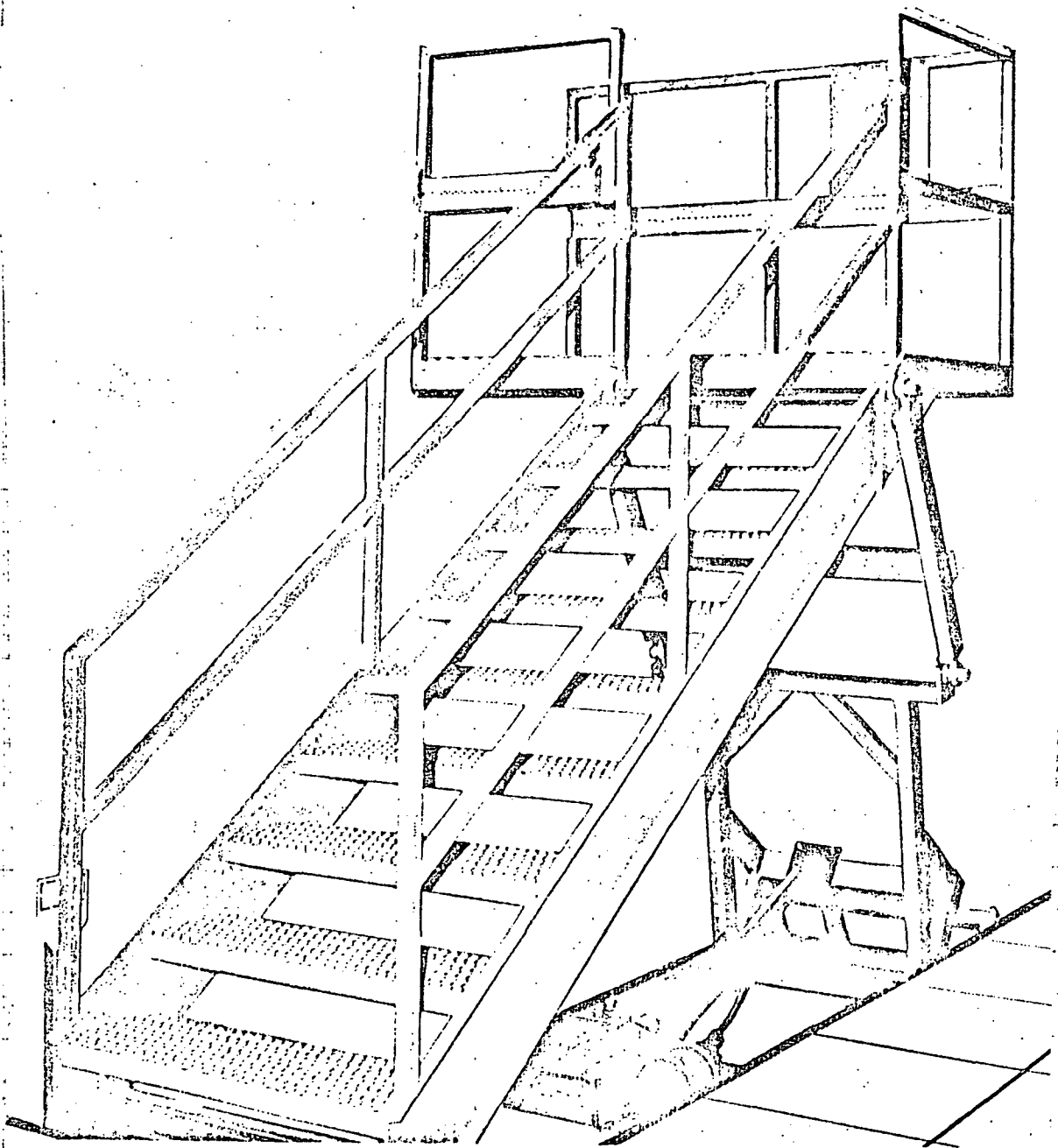


FIGURE 4.1.2-16

MOTION PLATFORM ACCESS STAIRWAY

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4.2 Crew Station

The crew station for the motion based simulator will contain all of the controls, displays, linings, seats and other equipment in the precise location of that in the actual vehicle, which are visible to the Commander and Pilot in the performance of their duties. Aft of this flight compartment the fidelity will be compromised to include the authentic seating provisions for the Mission and Payload Specialists but only those displays or controls at these stations which are associated with flight control.

In addition, a removable jump seat will be provided for an observer to be located aft of the center pedestal and approximately, six inches above the flight crew. This jump seat can be readily removed and contains seat belts to restrain the observer. It will be braced structurally to accommodate the observer in a full tilt attitude under the maximum dynamic loads.

Normal ingress/egress for the crew members will be through a conventional hinged door at the rear of the crew station, while the crew station is in a level position. An emergency hatch will be provided along the aft right wall of the payload specialist station to permit egress when the crew station is in a tilt position and the aft door is blocked by the platform.

The crew station is approximately 129" long x 140" wide a 91" high and, complete with 4 crew members, weighs an estimated 6,000 lbs.

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With reference to a crew eye position at Sta. 460 and W.L. 469 it extends longitudinally from approximately Sta. 411 aft to Sta. 540 (all B.L., W.L. and Station references refer to NR Drawing VL70-003047A). Vertically it extends from W.L. 406, approximately 4" beneath the crew station floor, to approximately W.L. 497 to permit installation of the lining around the overhead panels. Laterally it extends to B.L. 70 to include the panel beneath the Mission Specialist's shelf at B.L. 58 on the left side and to include the side hatch control panel at B.L. 66 on the right side.

It will be made in two discrete sections, a forward and aft section split at approximately Sta. 474, to accommodate shipping and to permit using identical forward sections for the motion based and fixed base simulators. Thus, the assembled forward section will be approximately 140" long x 63" wide x 91" high, and the aft section 140" long x 66" wide x 91" high.

The forward section will be tapered to nest within the forward visual system. The interior will be a high fidelity replica of the actual vehicle.

The aft section will be a less authentic replica of its vehicle counterpart except in the areas associated with flight control, with compromises in length, height and interior detail to reduce size, weight and complexity.

#### 4.2.1 Crew Station Structure

The crew station for the MBCS should be made in two sections. Each section should be designed to be as light as practical



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consistent with cost and rigidity requirements. Further, access and maintainability are prime considerations. It must be possible to remove the entire cockpit from the tilt frame without disturbing the visual alignment.

To accomplish these objectives each section will be complete with its floor frame, shell, seat linings, panels and cabling, requiring only structural and electrical connections to form the complete unit. Each unit will be sufficiently reinforced to permit removal from the tilt frame without major disassembly.

The floor frames will be welded aluminum multi-level frames simulating the floor frames of the vehicle and extending upward to support the majority of the weight of the consoles, panels and seats and to transfer these loads to the tilt frame structure.

A molded fiberglass shell will form the outer structure above the floor levels. The forward shell will contain the structural sills, window framing, and additional flanges to support overhead panels, lining, outer console attachments and upper attachments to the tilt frame structure. The aft shell will be reinforced to contain the entrance door, emergency escape hatch, and overhead attachment to the tilt structure, and also to provide a bearing surface to transfer side loading to the tilt pivot structure close to the motion platform.

The six forward windows will be bolted on sub-assemblies protruding outward from the inner window framing and simulating the field of view

as restricted by the multi-paned vehicle windows.

To the greatest extent possible all panels will contain provisions for removal for maintenance from within the cockpit, since external access will be obstructed by the visual system.

#### 4.2.2 Control Loading

The control loading for the MBCS will be defined by the characteristics of the individual vehicle control forces, travels, and automatic drives. Some controls are purely electrically activated and require only the vehicle switch. Others require manual operation where control output is proportional to control handle position. Among the controls requiring loading mechanisms are the rudder, toe brakes, throttles, speed brakes, and vehicle attitude controls.

Simulation for the throttle and speed brake controls will be a function of the specific characteristics of these controls in the vehicle.

Typically, a friction/position sensing unit is used for the throttle loading with either electric-motor driven or hydraulic servos employed for auto-throttle, or playback. The orbiter has dual controls for both throttles and speed-brake with one quadrant on the left console and the other quadrant on the center pedestal. These

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controls will be linked to common jackshafts located in the forward floor frame to facilitate interconnection. There are four throttle levers on the center pedestal and one on the left console. Hence linkage may be quite intricate, depending upon actual vehicle interconnection and what failures are to be simulated.

Wheel brakes simulation is also accomplished in many ways as a function of vehicle characteristics.

Loading mechanisms vary from mechanical bungees, to hydraulic actuators, to pneumatic actuators and combinations thereof depending on the vehicle operation and failures to be considered.

#### 4.2.2.1 Rudder Controls

The rudder controls are presently conceived to be conventional floor mounted dual controls typical of those on all large aircraft.

Typically, the rudder controls require high forces thus an electrohydraulic control loading servo will be employed to simulate the characteristics of the rudder system. Hydraulic power for this loading unit is supplied with the standard motion system equipment which has a separate 10 HP pump and a distribution manifold which permits pressure regulation to that required for the loading units. The pump has sufficient capacity to accommodate the hydraulic requirements of both the motion based and fixed base cockpits.

A typical control loading servo device, shown on Figure 4.2.2-1 is a closed loop servo system made up of the following major elements:

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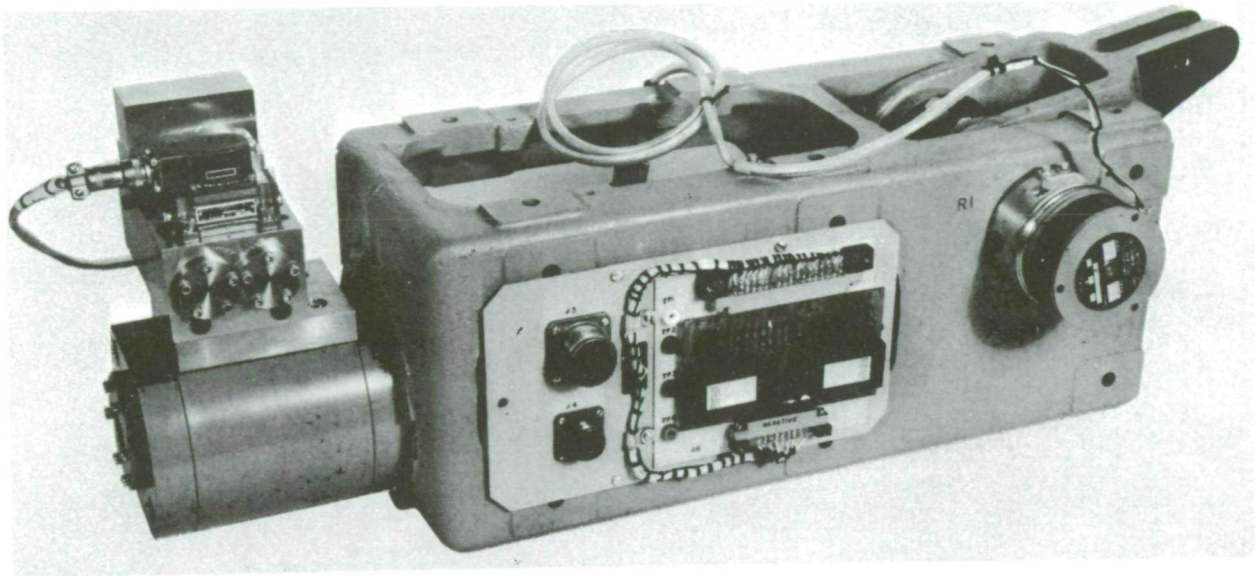


Figure 4.2.2-1 CONTROL LOADING SERVO



1) A semiconductor strain gauge load cell used as a force transducer. The load cell consists of four strain gauges arranged in a Wheatstone bridge. This bridge is balanced when the system is unloaded. The application of force or load causes two of the strain gauges to increase in resistance and two to decrease in resistance. The load cell uses the piezo-resistance characteristics of semiconductors to generate this effect. A DC output voltage is obtained (with polarity dependent upon tension or compression of the cell) by exciting the strain gauge with a DC voltage. The load cell has a nonlinearity less than  $\pm 0.003$  inches at full scale.

2) A film potentiometer used for sensing control position. The potentiometer has a  $\pm 0.25\%$  linearity and virtually infinite resolution.

3) Amplifiers and power supplies of solid state construction. To minimize pickup in the leads, critical amplifiers are located at the control loading servo.

4) A hydraulic/mechanical safety device which senses the rate of change of pressure as a function of flow. In the event that the triggering level of the device is exceeded, it automatically locks the control loading unit, preventing further motion from taking place. By this action the pilot is protected from a sudden hardover servo failure that could produce a violent pedal motion.

The control loading system is a rigid servo loop which cannot be moved without an electrical input.

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The output shaft of each servo is connected to the crew pedal arm through a force transducer. The force transducer produces an electrical signal (analogous to pilot force) that drives the servo in the direction of the force. The required force is computed and fed back to the pilot through the control. The force gradient is zero when the force transducer is the only input to the system.

This control loading device will be mounted in a location that will permit access for adjustment and maintenance.

#### 4.2.3 Crew Station Air Conditioning

Site supplied conditioned air will be used to ventilate the crew stations of the flight simulator. Air will be drawn from beneath the computer flooring of the IOS area into a filtered plenum by a booster blower which will augment the supply pressure to overcome the losses in the filter, flexible ducts to the crew station and visual system and outlet grilles. Refer to Figure 4.2.3-1.

The blower will run continuously to supply cooled air to instruments and to the visual system components. The air flow to the crew station will be ducted to a distribution plenum equipped with dampers and heaters which will respond to the flow/temperature settings of the spacecraft controls. The majority of the heat generated in the visual display will be removed by means of liquid cooling.

#### 4.2.4 Crew Station Suit System

The suit system will simulate that of the spacecraft for

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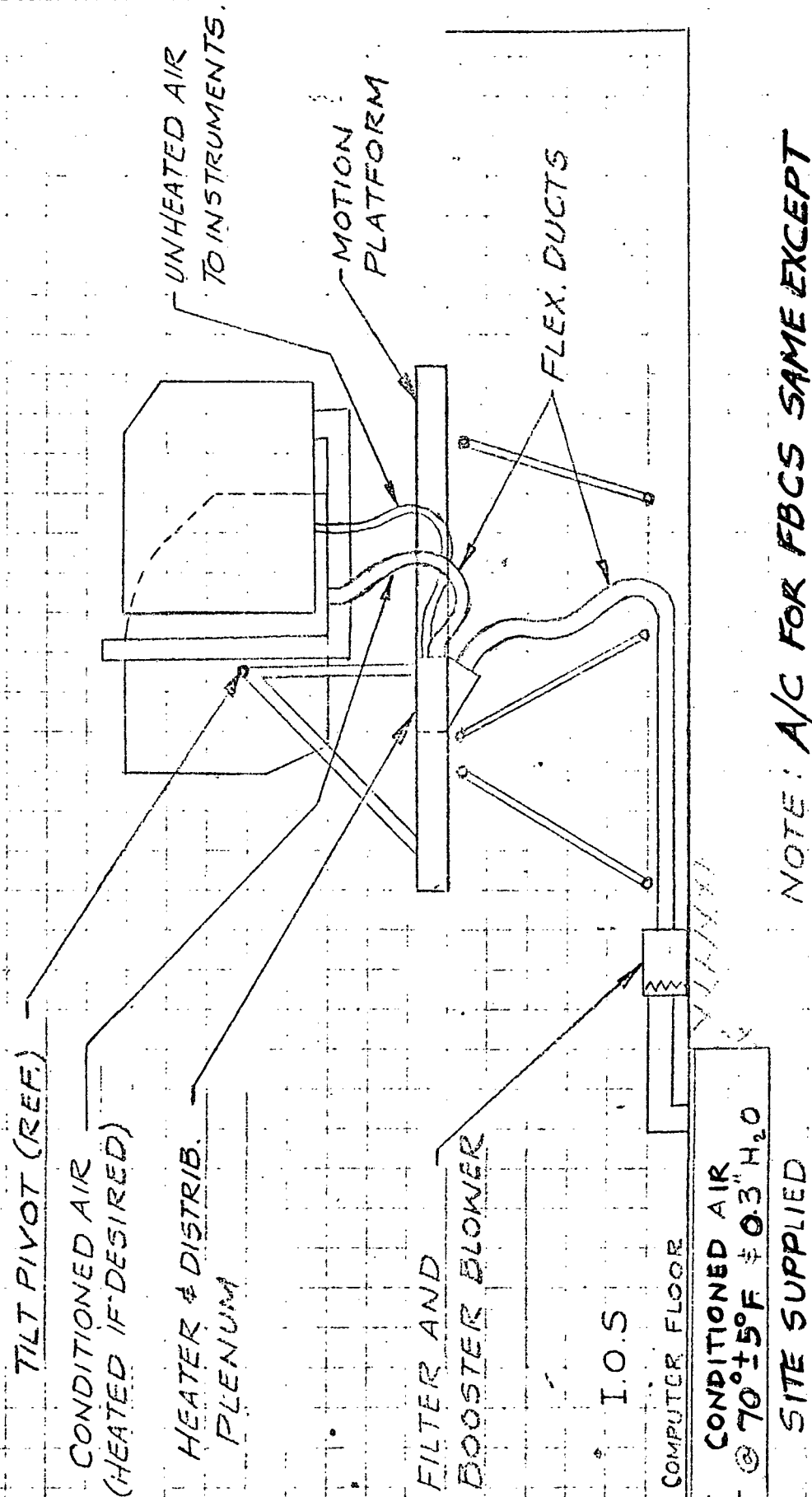


FIG. 4.2.3-1 - MBSC AIR CONDITIONING SCHEMATIC



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normal comfort conditions. Refer to Figure 4.2.4-1. The simulator will supply breathing and ventilation air to the outlets in the spacecraft. The air will be of breathing quality with 0.8 micron filters. It will be dried to a maximum relative humidity of 50% at 60°F. and atmospheric pressure to preclude damage to the personnel gear. The volumes of air supplied will be capable of maintaining the suit pressures at 3.5 psig with suit vent controls set at normal flow.

The system will include safety relief valves at each outlet to preclude overpressurization of the suits. Gauges and pressure controls will be installed near the crew stations to permit periodic check-out of the suit system for each crewman. Suit pressure will simulate that of the spacecraft system for changes in synthetic cabin pressure except that the rate of change of suit pressure will be deliberately retarded by a servo to preclude discomfort to the crew.

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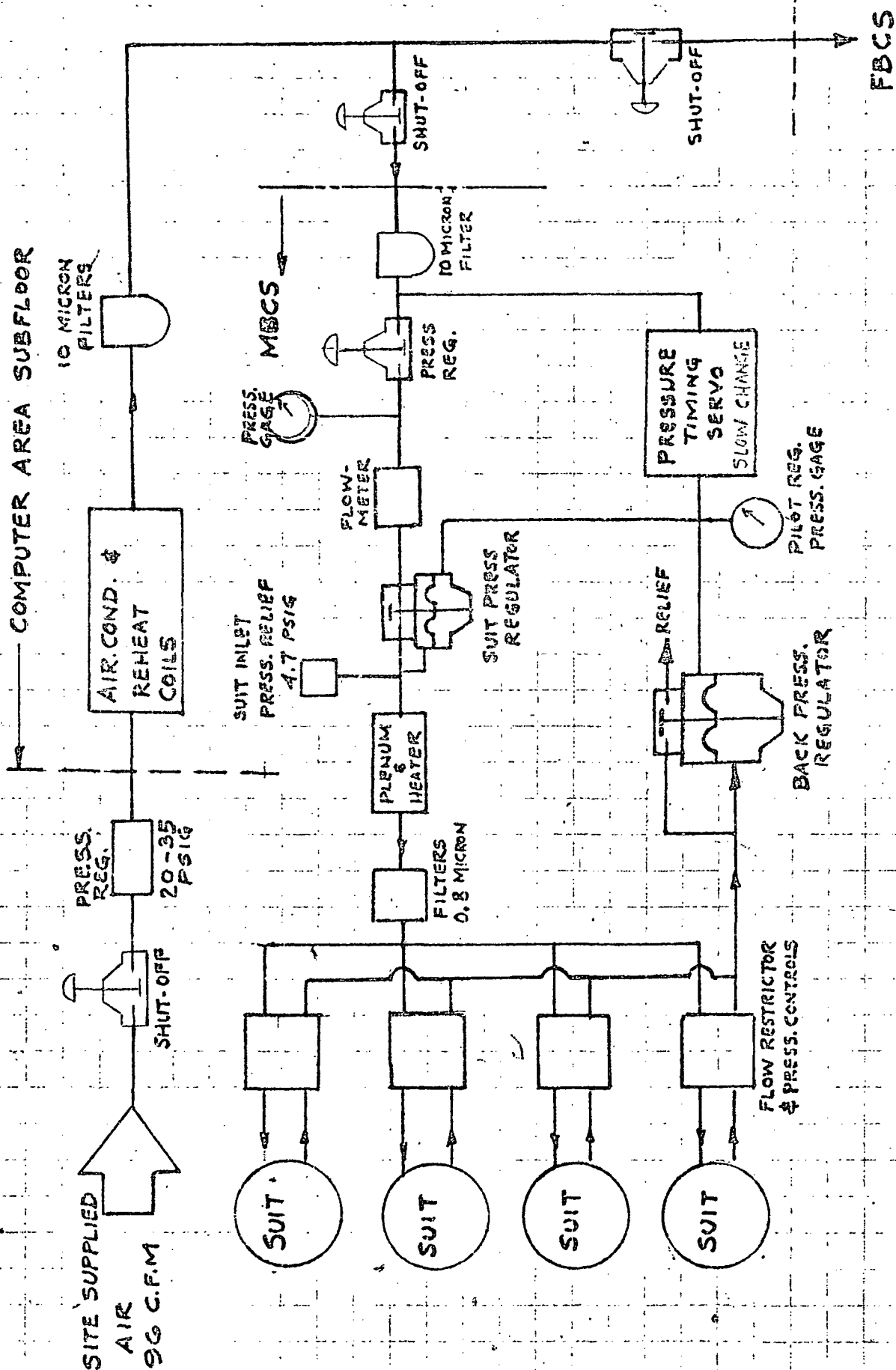


FIG. 4.2.4-1 - SCHEMATIC OF PRESS. SUIT SYSTEM

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#### 4.2.5 Crew Station Control and Display

In the MBCS, each Crew Station control and Display associated with the Shuttle Vehicle Commanders and Pilots Stations will be duplicated in appearance, location, color, action and reaction to the high degree required for crew training.

Additional MBCS crew station controls and displays associated with the Mission Specialist and Payload Handling will be simulated by mockup but will not be functional. Refer to Addendum A for panel outline drawings and crew station locations.

All crew station CRT's and associated keyboards will be supplied GFP. This equipment is located on panel numbers 400, 500, 600, and 255 on the MBCS; and on panels 400, 500, 600, 255, 201, 101, and 100 on the FBCS. Information will be transmitted to the CRT's through serial data channels and will interface with the DP&S Subsystem computers without the need for DCE.

Electrical system schematic diagrams for typical SMS control and displays are shown below.

##### A) Analog Functions

##### 1) Potentiometers

Control

e.g. Hand Controllers; position feedback from speed brakes, throttles

Control knobs and other continuously variable functions will input their position to the computer via an analog-to-digital (A/D) device, located in the DCE. See Figure 4.2.5-1.

## 2) D'Arsonval Meter Movement Instruments

e.g. RCS Press indicators, OMS Fuel Tank indicators

Meter Movement Instruments will be driven directly from a D/A through series, scaling resistors. Where possible these resistors will be mounted on the rear of the instrument thereby allowing setup by a single technician and eliminating the need for a circuit card in the peripheral cabinet. See Figure 4.2.5-2.

## 3) AC Synchro Instruments

e.g. Course Ind. & FDAI (multiple synchros).

Each AC Synchro Instrument will be driven by an Electronic Synchro Resolver Driver (ESRD) which, in turn, is driven from the DCE by a pair of Digital-to-Analog (D/A) Channels. See Figure 4.2.5-3.

B) Digital Functions

## 1) Toggle Switch

Typical wiring for this switch is as shown in Figure 4.2.5-4.

## 2) Toggle Switch (center off)

Toggle Switch (2 position, center OFF): Typical wiring for this switch is as shown in Figure 4.2.5-5.

## 3) Illuminated Switches

Illuminated switches will be wired as shown in Figure 4.2.5-6. Two-position switches will require one digital input (DI) channel.

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Multiple position switches will require  $(n-1)$  DI's, where  $n$  = the number of switch positions. This figure shows an indicator with the capability of two color changes.

#### 4) Multi-position Rotary Switch

Typical wiring for this type of switch is as shown in Figure 4.2.5-7.

The number of Digital Inputs (DI) is equal to  $(N-1)$  switch positions.

#### 5) Press to Test Indicators

Press-to-Test Indicators which require additional power logic for test will require two digital output (DO) control channels. Where the test position only requires a ground to test, the DO at the test position will be replaced with a ground point. See Figure 4.2.5-8.

#### 6) Indicators

Indicators will be wired as shown. Where one color is required, all bulbs will be wired together and only one DO will be used. See Figure 4.2.5-9.

#### 7) Digital Readout

The digital readout shown has a built-in BCD decoder which accepts an 8, 4, 2, 1 code to display a 0 9 readout. Each readout will be driven by discrete DO's or, by a digital-word-output (DWO). See Figure 4.2.5-10.

## 8) Circuit Breakers

All crew station circuit breakers will be remotely poppable through the computer. Special, low-current circuit breakers will be used instead of spacecraft equipment for the SMS.

The breakers can be made to be "resettable" or "non-resettable" by means of programming. A "resettable" breaker can be reset by the student after it is remotely tripped; whereas a "non-resettable" breaker will trip or "pop" as soon as resetting is attempted.

Double-pole, double-throw contacts will enable the circuit breaker to feedback to the computer that it is tripped or pulled as well as having the capability of being hardwired in the simulated circuit. See Figure 4.2.5-11.

9) All cockpit lighting controls on simulated panels will be operative. Lighting will be variable where required and will be duplicated in visual light intensity to that of the space vehicle.

Electroluminescent lighting will be used where applicable and operate as in the space craft. Lighting controls are located on panels 800, 700, 352, 255 and 102. Step-up transformers will be located near their loads to minimize pickup.

Power logic will be incorporated in all circuits and overload protection will be supplied.

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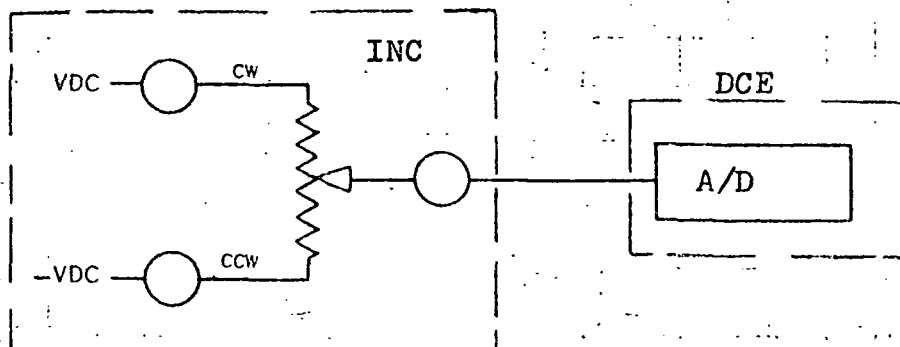
PNL 350  
TEMPERATURE CONTROL KNOB

Figure 4.2.5-1 Pots and Controls

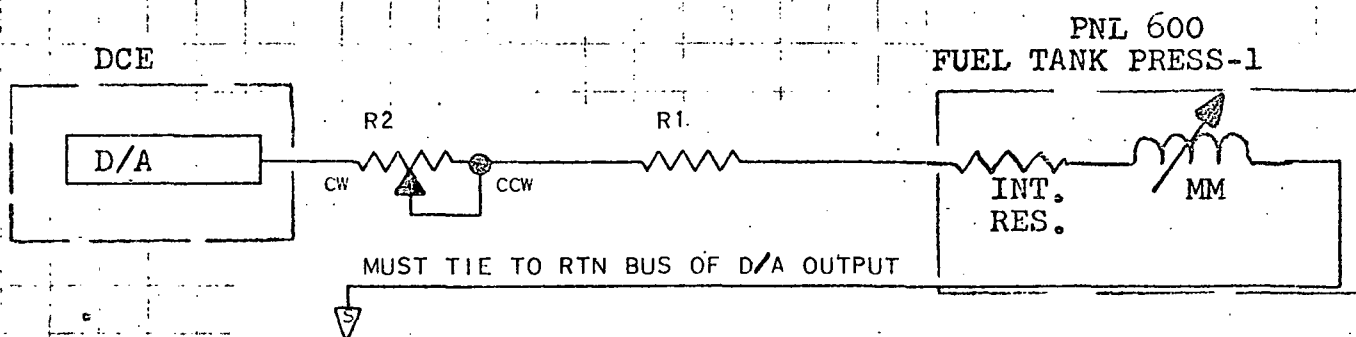


Figure 4.2.5-2 D'Arsonal Meter Movement Inst.

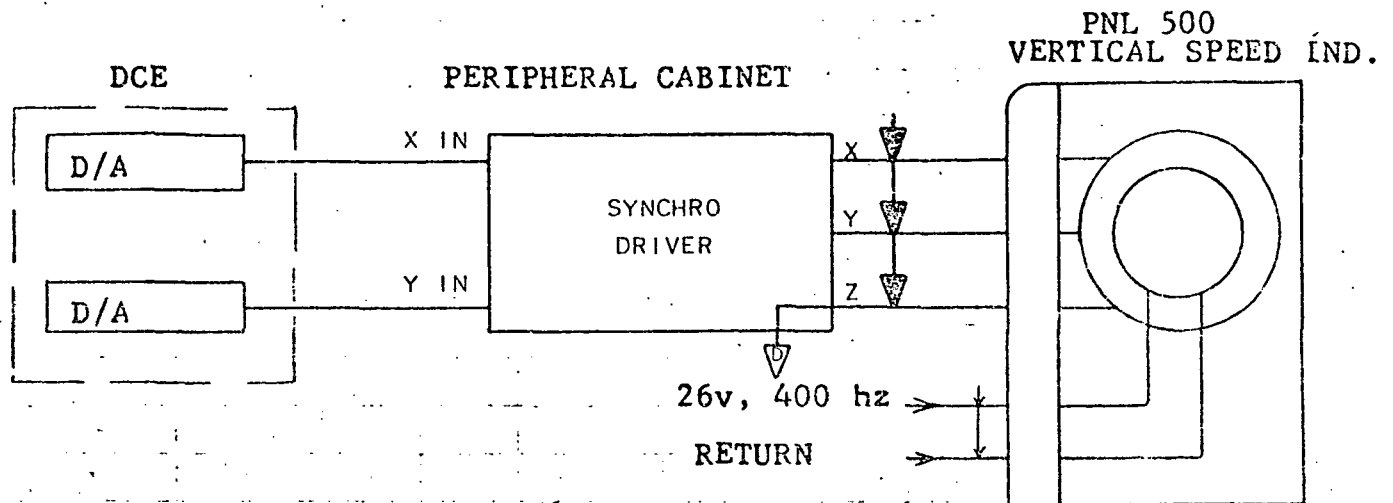


Figure 4.2.5-3 AC Synchro Instrument

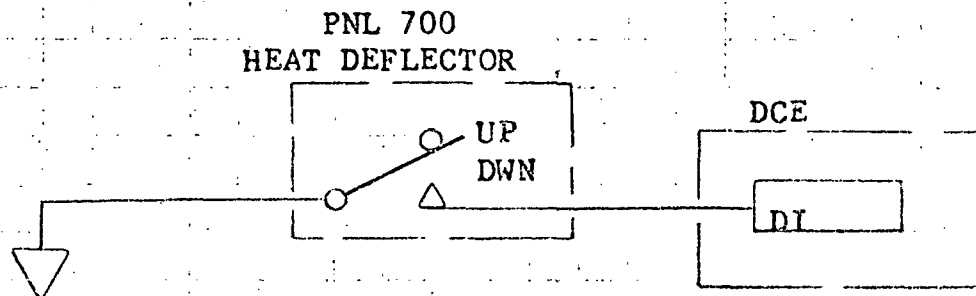


Figure 4.2.5-4 Toggle switch

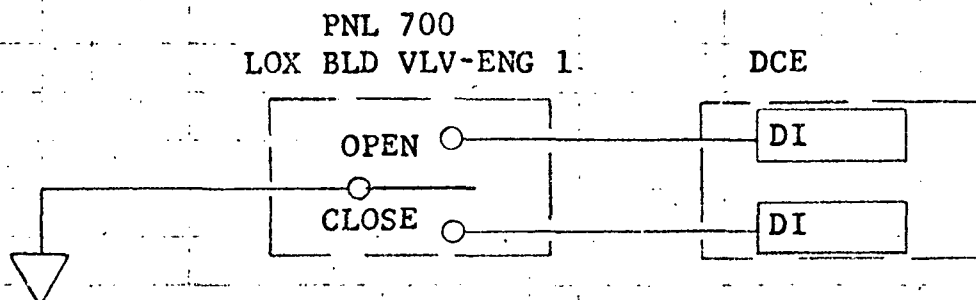


Figure 4.2.5-5 Toggle switch (center off)



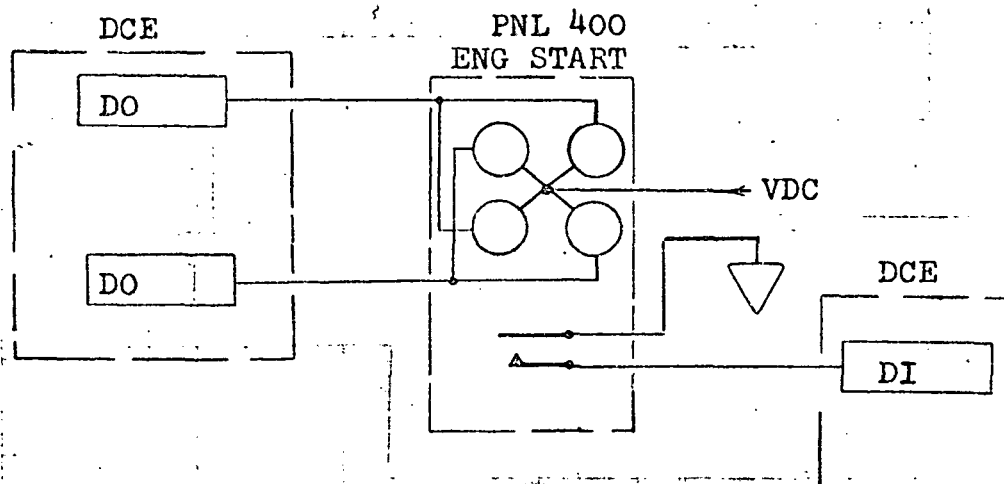


Figure 4.2.5-6 Illuminated Switches

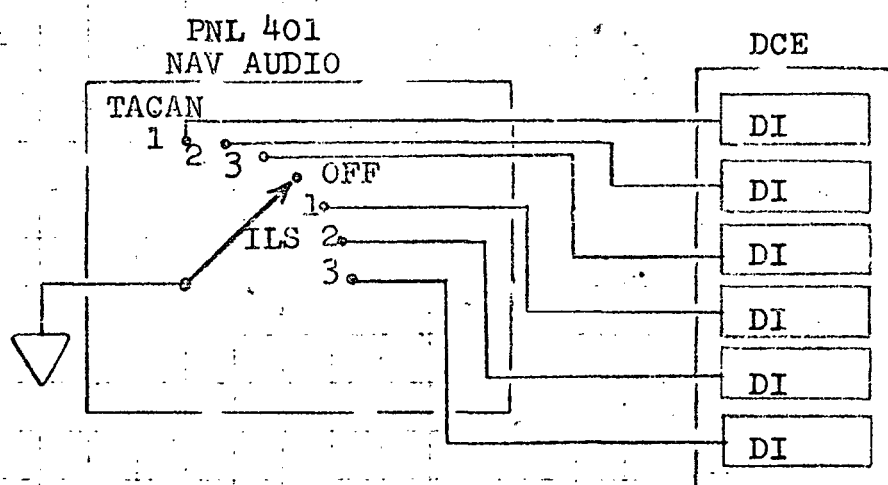


Figure 4.2.5-7 Multi-position Rotary Switch

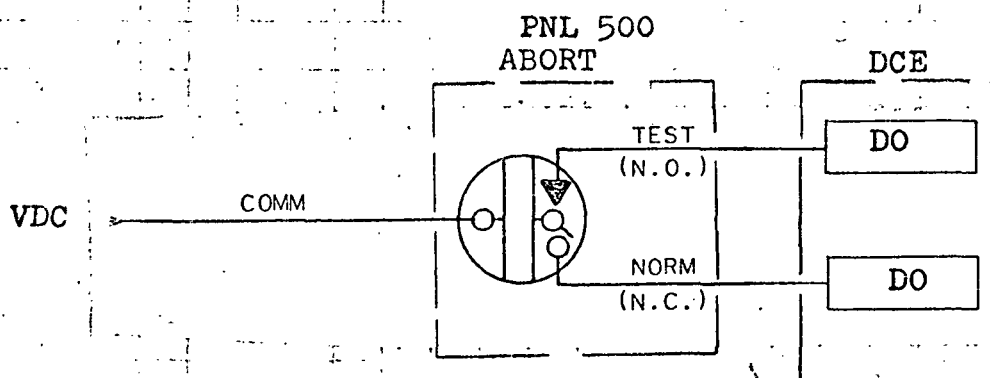


Figure 4.2.5-8 Press-to-test Indicators

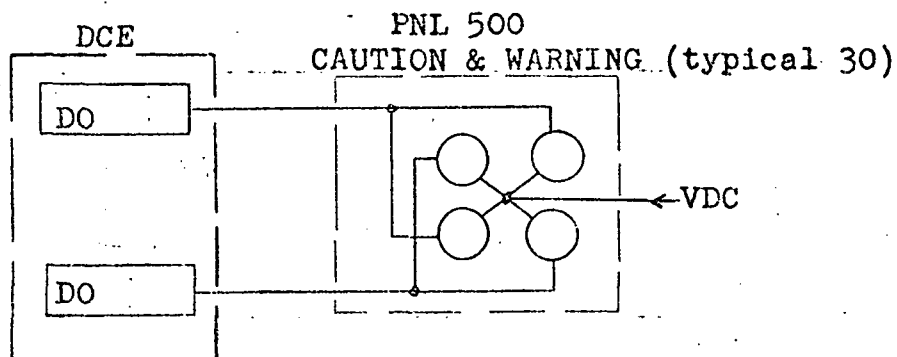


Figure 4.2.5-9 Indicators

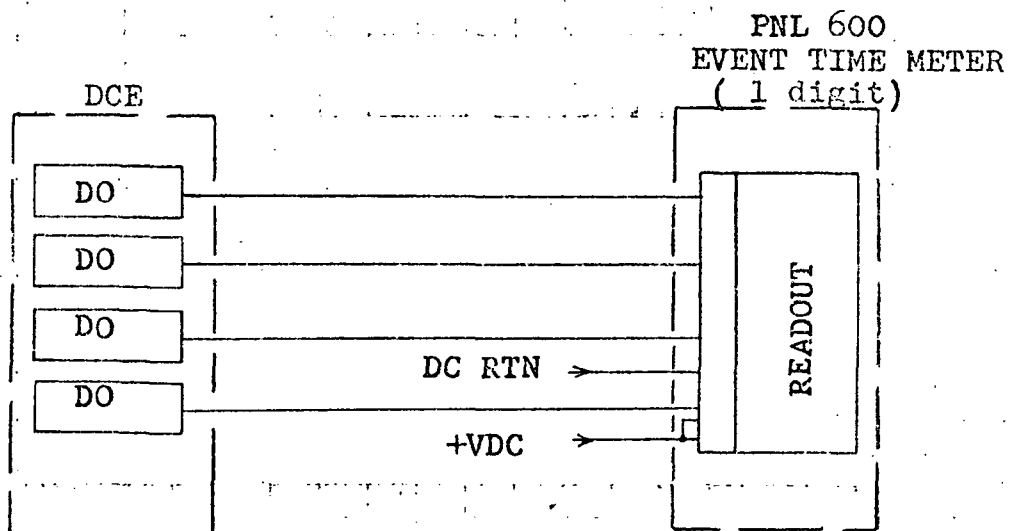


Figure 4.2.5-10 Digital Readout

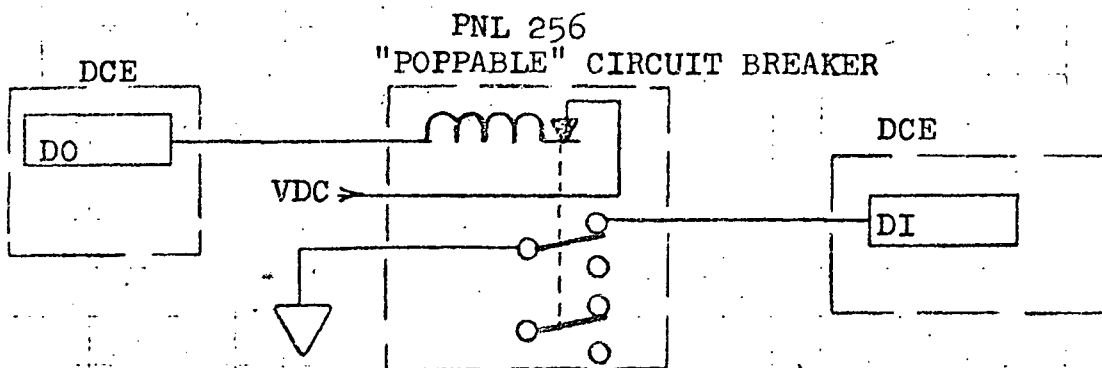


Figure 4.2.5-11 Circuit Breakers

#### 4.3 Instructor-Operator Station

Several configurations of the Instructor-Operator Station (IOS) were considered for the SMS. The configurations were limited to a conventional-type IOS since the availability of space in the crew cabin precluded the consideration of in-cabin instructor stations. However, the capability does exist for an instructor to observe trainee performance in the motion-based simulator during those periods when the Mission and/or Payload Specialists' seats are not occupied. On those occasions, limited control of the training exercise would be provided through a portable control box. On most occasions, instruction would be conducted from the conventional IOS.

The configuration of the conventional IOS narrowed down to an IOS for the motion-base crew station and one for the fixed-base crew station. The IOS for the motion-base crew station would permit monitoring of training exercises for all phases of flight except docking and payload handling. The fixed-base IOS would accommodate instruction for all phases of flight associated with space and aerodynamic operation. A separate IOS for each crew station provides the flexibility of instructing on both crew stations at the same time. A single IOS for both devices would not provide this feature, and would result in inefficient utilization of training time.

The motion-base crew station will be used primarily to train the Commander and Pilot. It will also be used to train the Mission Specialist and Payload Specialist in those duties required to assist

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the Commander and Pilot. Panels dedicated to Mission and Payload Specialist functions will not be functional in the motion-base crew station. As a result, the IOS associated with this crew station will be concerned with training relative to the forward cabin.

The fixed base crew station will provide training associated with the aft cabin. In addition, training associated with space operation would be provided for the forward station. The IOS for this simulator will be equipped to provide instruction for all crew positions, including the OMS station. Integrated training with MCC will be provided from either IOS. Because of the number of crew positions to be trained on the SMS, the IOS will be designed in modular form. The following modules would comprise the fixed-base IOS: (1) Commander and Pilot, (2) Telemetry, (3) Orbital Maneuvering Station, (4) Mission Specialist, and (5) Payload Specialist. The Telemetry Operator Station is shared by both the motion-base and fixed-base crew stations.

#### 4.3.1 Commander/Pilot Instructor-Operator Station

The simulator complex will consist of two Commander/Pilot IOS's; one for the motion-based simulator, and one for the fixed-base simulator. Design of these IOS's will be identical, except for those special controls required to perform training device peculiar functions. As an example, only the motion-based simulator will contain those controls required for the operation of the motion system.

The Commander/Pilot IOS is designed to be operated, on most training exercise, by two instructors; one for the Commander, and one for

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the Pilot. When training is to be conducted for just one crew member, only one instructor will be required to man the console.

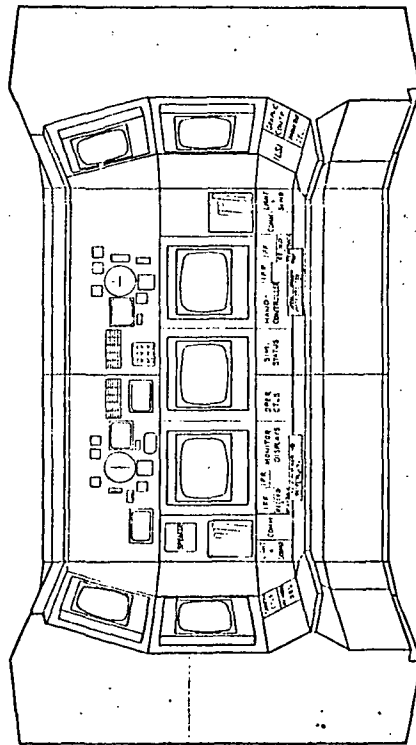
In addition to the console, the IOS includes:

- a. One X-Y recorder
- b. Three eight-channel time history X-T recorders
- c. Two castored, fully adjustable, swivel armchairs.
- d. One hard-copy print-out device.

#### 4.3.1.1 Motion Base Crew Station

The instructor-operator console integrates five CRT display/keyboard units, two visual system monitors, dedicated displays, a control panel used for functions not accomplished with the keyboard units, and an audio panel to provide the necessary communications functions. (Reference Figure 4.3-1 ). The console utilizes horizontal wraparound to provide for ease of viewing the CRT's and monitors, and to fascilitate interaction between the two instructors. The console is also vertically stacked. The upper segment is canted downward 30 degrees from the vertical, the middle segment is vertical, and the lower segment is inclined 45 degrees from the horizontal, and joins the horizontal writing surface. The writing surface is 16 inches deep to provide adequate space for reference materials (manuals, mission plans, etc.) and for writing. The height of the writing shelf above the floor (25½ inches, in conformity with MIL-STD-1472) allows the keyboard units to be at a comfortable level and yet provides ample knee room for the instructor.

The center portion of the instructor console contains the



PILOT COMM. CONSOLES  
I/O STATION-  
MBCS & FBCS SIM.  
FIGURE 4.3-1.

[illegible][illegible]

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dedicated instruments on the upper segment; the vertical segment contains two alphanumeric CRT's and a CRT dedicated to Event Time Monitoring functions; the lower inclined segments contains operating controls. The left portion of the console is wrapped-around 45 degrees and contains a visual system monitor on the upper segment, a graphic CRT on the vertical segment, and operating controls on the lower inclined segment. The right portion of the console, also wrapped-around 45 degrees, is a mirror image of the left portion of the console.

#### 4.3.1.1.1 CRT Display/Keyboard Units

The IOS for the motion base crew station will contain provisions for two instructors; one for the Commander, and one for the Pilot. Each position of this station will be equipped with a sufficient number of CRT's for each instructor to completely monitor the performance of the crew members. To accomplish this objective, each instructor will be provided with three CRT's. The function of the CRT's are to provide: (1) an alphanumeric display, (2) a graphic display, and (3) a monitor of the visual system. In addition, a fourth CRT, centrally located between the two instructors, will be provided to observe Event Time Monitoring functions. Three additional monitors which duplicate the in-cabin CRT's will also be provided and located in the cluster of dedicated instruments centrally located between the two instructors.

Alphanumeric or graphic data may be displayed on either of the CRT's at any position of the IOS at the option of the instructor.

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e.g., at any one instructor position, alphanumeric data may be displayed on both CRT's; graphic data on both; alphanumeric on one and graphic data on the other, or vice versa depending on the intelligence required on the training exercise.

The Keyboard/Display units will operate identically; the same displays will be available at each position, and the same keyboard action will be used at each position to select a display or modify a value stored in the computer. In addition, each CRT will be able to display and perform control actions independent of the other. The top line of the CRT will always contain the following items:

- a. A one-or two-character display mnemonic identifying the display
- b. Symbols indicating the ground station in contact with the vehicle; if none are in contact, LOS (Loss of Signal) will be displayed
- c. Mission elapsed time (MET)
- d. Simulated Greenwich mean time (GMT)

The top line of the CRT would be displayed as follows:

XX LOS

METXXX:XX:XX GMTXXX:XX:XX

Space is available on the top line to the left of "MET" for computer generated alerts to the instructor informing him of any events which may cause him to want to change the page or take other action.

The following is a listing of CRT pages which will be provided:



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- a. Event Time Monitor
- b. Panel Displays (excluding those provided by dedicated displays)
- c. Energy Management Predictor
- d. Malfunction Insertion and Display
- e. Circuit Breaker Status
- f. Crew Station Set-up Verification
- g. Active Malfunctions and Tripped Circuit Breakers
- h. Mission Parameters and Summary Display
- i. Interface Data Stream and Telemetry Monitoring
- j. Enroute and Approach Display
- k. System Schematic Displays
- l. Programmed Demonstration
- m. Training Exercise Display
- n. Performance Monitor Display
- o. External Environment
- p. Simulator Reset
- q. Simulator Status

Each of the display categories will be identified by a one- or two-character mnemonic. The first character being a letter to identify the category, and the second character - when there is more than one page in the category - denoting the page within the category. To select a page, the instructor will press a key labeled "PAGE SELECT" on the special function keyboard and then insert the one or two required characters through the normal typewriter keys.

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To take an action through the keyboard, the line on the appropriate page will be selected by pressing the "LINE SELECT" key on the special function keyboard and then typing in the line identifier.

When a line is selected, it will be repeated at the bottom of the CRT, and the cursor, under computer control, will identify the first modifiable character. The keyboard will be used to "write-over" characters or blank spaces on the bottom("scratch pad") line to be modified. Backspacing can be used to correct entries. When the instructor verifies that the bottom line is correct, he will press the "INSERT" special function key which will replace the contents of the line selected with the contents of the "scratch pad" line and the "scratch pad" line will be erased.

Where a line contains more than one modifiable character, depression of the "TAB" key will cause the cursor to advance to the next modifiable character. Illegal actions, i.e., writing over labels will not be executed.

To clear a line that has been selected, and is copied on the "scratch pad" line, of all instructor-inserted characters, and restore

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it to its normal conditions, the "CLEAR" function key will be depressed. When the simulator is reset from a "FREEZE" mode, the displays on the CRT will also be reset. Thus, all instructor insertions on all CRT pages will be cleared when the simulator is reset to a set of initial conditions.

The entire process - the formatting of displays, the means for display selection, and the selection of methods for taking actions using the keyboard has been human-engineered to make displays easy to select and to read, and control actions rapid and simple. The system described accomplishes needed actions with a few keystrokes, mnemonically coded to minimize human memory requirements.

#### 4.3.1.1.1.1 Event Time Monitor

A CRT located between the two instructors will be dedicated to the Event Time Monitoring functions. The CRT will provide a chronological display of the most recent crew actions. The most recent crew action will be displayed on the top line of the CRT. As the next action takes place, it will occupy the first line, and the previous action will occupy the second. When the CRT page is filled, a new crew action will cause the last line on the page to be dropped from the display. Each line will contain the following data:

- a. The name of the control manipulated.
- b. The action taken: For a non-momentary switch, the new position will be displayed. For a momentary switch or continuous

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control, the direction of the most recent motion would be shown.

c. The time at which the action occurred.

d. The mnemonic of the Panel page involved.

4.3.1.1.1.2 Panel Displays

Panel displays are basically repeaters of spacecraft control positions and displays. The panel displays will include all systems except those which are presented on dedicated displays. They also serve the function of parameter override (allowing the instructor to view a display other than the one present in the vehicle, and to view the true value of a display that has malfunctioned) and parallel switch operation (allowing the instructor to override the position of controls at the crew station). The repeater function enables the instructor to monitor trainee activities and to observe the reaction of the crew in rectifying errors and malfunctions and in performing their mission tasks. These displays will be displayed by panels as they appear within the vehicle.

Within each panel, there may be a number of display pages depending upon the number of controls and indicators available to the crew. Selection of the Panel Display through the keyboard will present a Panel Display Index to the instructor. The index will provide the instructor with the mnemonic of the particular panel desired. Insertion of the panel mnemonic into the keyboard and pressing "PAGE SELECT" on the special function keyboard will cause the panel display page to be presented to the instructor. Panel pages will present to the instructor

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a display of the control and indicator positions presented in the cabin. Controls will be displayed as follows:

a. Continuous Controls: This type control will be displayed as a vertical rectangle. A scale will be located within the rectangle representing the range of the control. An index, also located within the rectangle will represent the present indication of the control. The control will be identified by its name.

b. Continuous Displays. This type of device is displayed in the same manner as Continuous Controls.

c. Switches. A tabular listing of system switches will be displayed. The listing will include the switch name and all available switch positions. The symbol ☐ will be placed to the left of the switch position prevailing in the vehicle, an asterisk (\*) will be placed to the left of the position selected by the instructor for parallel switch operation, or, in the case of display selecting switches for parameter display override.

d. Digital Displays. These displays will be presented in the same manner as in the vehicle. Commas, decimal points, and other symbols (e.g., N, S, E, W, +, -) will be appropriately displayed.

e. Quasi Digital Displays (Flags) Display of this type will be accomplished by a colored symbol.

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#### 4.3.1.1.1.2.1 Parameter Display Override

Parameter display override will be usable in two different ways: (1) to view a display other than one present in the vehicle, and (2) to view the true value of a malfunctioned display. To accomplish the former, action will be taken at the representation of a switch position on the CRT; to accomplish the latter, action will be taken at the parameter display itself. All that will be required is to place an asterisk to the left of the switch position name in the first case, and to the left of the label of the display in the second case, using the same procedure described below for Parallel Switch Operation.

#### 4.3.1.1.1.2.2 Parallel Switch Operation

Placing an asterisk to the left of the name of a switch position selected by the instructor is all that is necessary to accomplish parallel switch operation. This will be done as follows. First, the CRT line containing the name of the desired switch position will be selected by pressing the "LINE SELECT" and the line designator keys. This will bring a copy of the selected line to the bottom or scratch pad line. The cursor will be positioned at the first instructor-modifiable space or symbol. If this is not the space or symbol the instructor wishes to modify, he will hit the "TAB" key. Each depression of which will move the cursor to the next instructor-modifiable space or character. Upon reaching the desired space, an asterisk will be typed in. Following this, the instructor will verify his action visually, and if correct, he will press the "INSERT" key. This will accomplish three things:

a. Establishment of parallel switch operation

b. Insertion of the asterisk on the selected line in the main body of the display and

c. Erasure of the scratch pad line

Parallel operation will be deleted by going through the same procedure, except that a blank space will be typed over the asterisk, rather than an asterisk over the blank space.

#### 4.3.1.1.1.3 Energy Management Predictor Display

This page will provide a graphic display of the critical parameters associated with energy management. The display will contain a symbol indicating the vehicle's current state and a second symbol which will predict the vehicle state. Predicted values of energy management parameters will be displayed in 30 second increments.

To select the Energy Management Predictor page, the instructor will depress the "PAGE SELECT" key on the special function keyboard and the mnemonic assigned to this page on the keyboard.

#### 4.3.1.1.1.4 Malfunction Insertion and Display

This feature will provide the instructor with the capability of entering malfunctions into any subsystem of the SSV and faults into the telemetry. Provisions will be made for both automatic and manual insertion of malfunctions. Automatic insertion of malfunctions will be a feature of the preprogrammed training exercises and will require no action on the part of the instructor. The conditions for automatic malfunction insertion will be specifiable in terms of

simulator/trainee events as well as in terms of time into mission.

Manual insertion of malfunctions and faults will be accomplished through the keyboard unit. To call up a malfunction, the instructor will first select the Malfunction Insertion and Display page. This page is an index which categorizes malfunctions by system and the associated mnemonic for the system malfunction page. Inserting the appropriate mnemonic into the keyboard unit and pressing the "PAGE SELECT" key will cause the selected malfunction page to appear on the CRT. The display page will contain a mix of discrete and variable malfunctions, one malfunction per line.

To insert a discrete malfunction, the line will be selected by depressing the "LINE SELECT" key on the special function keyboard and the line identifier. This action will copy the selected line on the scratch pad at the bottom of the CRT, with the cursor at the third space. The instructor types in an asterisk in the position marked by the cursor. After visually verifying his action the instructor will press the "INSERT" key. This will accomplish the following:

- a. Place an asterisk to the left of the malfunction listed on the page,

- b. Insert the malfunction into the system,

- c. Erase the scratch pad.

To enter or modify a variable malfunction, that line will be selected by depressing the "LINE SELECT" key and the appropriate line identifier key. This will copy the line on the scratch pad at



the bottom of the CRT. For variable malfunctions, the range and its units are provided after the malfunction. When the malfunction is copied on the scratch pad a cursor will appear two spaces after the last symbol. The instructor will type in the value of the variable malfunction above the cursor. After visually verifying his action, the instructor will press the "INSERT" key, which will:

- a. Place an asterisk to the left of the malfunction listed on the page
- b. Add the value of the inserted malfunction to the right of the listed malfunction,
- c. Introduce the variable malfunction into the system and
- d. Erase the scratch pad line

To modify a malfunction already in the simulator, the line will be selected as before. Since the first instructor-modifiable character will be the asterisk, the cursor will line up below it. Since the instructor wants to change rather than delete a malfunction he will press the "TAB" key to move the cursor to the next modifiable character, the previously inserted value of the variable malfunction. The instructor will then type over the previously inserted value with the new value he wishes to insert. Verification and insertion will be accomplished as described previously.

The presence of an asterisk to the immediate left of a listed malfunction indicates that malfunction is active. A quick scan will enable the instructor to locate any active malfunctions among

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those displayed on a page. To obtain a listing of all active malfunctions the instructor would use the display of active malfunctions and tripped circuit breakers described in 4.3.1.1.1.7.

When automatic malfunction insertion is in operation, the instructor will have the capability of overriding a previously programmed malfunction. If the malfunction is already active, it will be deleted using the procedures described above. If the malfunction is to be inserted in the future, the malfunction will be inserted through the Training Exercise Display page described in 4.3.1.1.1.13.

#### 4.3.1.1.1.5 Circuit Breaker Status

Tabular displays, organized by system by panel, will indicate for each circuit breaker its status: normal, permanently failed, temporarily failed or open. Using this display, the status of any circuit breaker can be changed to permanently failed or temporarily failed.

To call up the Circuit Breaker status display the instructor will press the "PAGE SELECT" key, followed by the mnemonic for circuit breaker status. This action will display an index of the circuit breaker status pages and the mnemonic associated with each circuit breaker status page. Inserting the appropriate mnemonic and pressing the "PAGE SELECT" key will cause the selected circuit breaker page to appear on the display. Panels containing more than 58 circuit breakers will require more than one page; panels containing fewer than ten will be grouped together on a single page.

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The format of the display would appear as follows:

BC LOS

MET 024:56:12 GMT 131:12:34

LINECIRCUIT BREAKERPERMTEMP

The "LINE" column would contain the line identifier.

"CIRCUIT BREAKER" would contain a listing of the circuit breakers contained on a given panel. The status of the circuit breaker would be indicated by an asterisk in the appropriate column.

Four kinds of actions can be taken by the instructor with respect to circuit breakers: (1) permanently fail a circuit breaker, (2) temporarily fail a circuit breaker, (3) change from permanently failed to temporarily failed, and (4) change from temporarily failed to permanently failed. Each of these actions is accomplished by replacing an asterisk in the "PERM" or "TEMP" column with a blank space, replacing a blank space with an asterisk or both. This is accomplished in the following manner:

a. The line containing the circuit breaker whose status is to be changed is selected by depressing two keys; "LINE SELECT" and the line designator. This brings a copy of the line content to the bottom scratch pad line. The cursor will be positioned at the "PERM" column of the scratch pad line.

b. The instructor types in an asterisk if he wishes to insert a permanent failure or change the failure from the temporary to permanent. If the latter, the asterisk in the "TEMP" column is erased when the one in the "PERM" column is typed in. If he wishes

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to change a failure from temporary to permanent, he types in a blank, erasing the asterisk.

c. If the instructor wishes to insert a temporary malfunction in an operating circuit breaker, he hits the "TAB" key, which moves the cursor to the "TEMP" column, and then types the asterisk there. When the cursor is in the "TEMP" column, a temporary failure can be changed to a permanent one by typing over the asterisk with a blank, thus moving the asterisk to the "PERM" column. Circuit breakers cannot, of course, be reset from the instructor's station.

d. Following modification of the scratch pad line, the instructor verifies his action, and if correct, presses the "INSERT" key.

#### 4.3.1.1.1.6 Crew Station Setup Verification Display

The purpose of the crew station setup verification display will be to enable the instructor to rapidly verify, prior to initiating an exercise at a reset point that the crew controls are in their proper position. To call up this display, the instructor will press the "PAGE SELECT" key followed by a two-letter mnemonic. The first letter will identify the crew station setup verification display and the second letter will correspond to one of the 20 reset points at which the simulator can be initialized by activating a reset.

The display will contain three columns, headed "CONTROL", "DESIRED POSITION", and "ACTUAL POSITION". The names of up to TBD controls whose desired and actual position differ will be displayed,

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along with the desired and actual positions. The format of the display would appear as follows:

VC LOS  
CONTROL

MET 024:56:12 GMT 131:12:34  
DESIRED POSITION ACTUAL POSITION

Since this display will normally be used when resetting to one of the reset points, it will be automatically called up to one of these 20 points using the procedures described in 4.3.1.1.1.16. If more than 25 controls are not in their desired positions, the line below that for the 25th control will contain a legend appraising the instructor of that fact. Since the circuit breaker status will be displayed elsewhere, one line of the display will be reserved for a summary of circuit breaker status. The appearance of the legend "CIRCUIT BREAKER" will indicate that one or more of the circuit breakers in the vehicle should be reset or tripped. Their identity can be determined by reference to the display of active circuit breakers described in 4.3.1.1.1.7.

#### 4.3.1.1.1.7 Active Malfunctions and Tripped Circuit Breakers

This display will provide, in one place, a listing of all active malfunctions and tripped circuit breakers. Using it, the instructor will be able to clear malfunctions individually or simultaneously. This display will contain all the lines in the malfunction and circuit breaker displays that have an asterisk in them, that is, all active malfunctions, discrete or variable, and all tripped circuit breakers: those permanently failed by the instructor, and those temporarily failed by the instructor. The instructor will be able to delete a malfunction or modify a variable malfunction with the display in the same manner

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as with the regular malfunction displays, but he will not be able to insert a malfunction with it, since only active malfunctions will be displayed. In a similar manner, the instructor will be able to change the status of a previously failed circuit breaker from permanently failed to temporarily failed, or vice versa. He will not be able to fail untripped circuit breakers with this display since only tripped circuit breakers will be indicated.

The line above the scratch pad will be labeled "CLEAR PAGE". When this line is selected and inserted, all malfunctions will be cleared, and all circuit breakers will be made resettable.

#### 4.3.1.1.1.8 Mission Parameters and Summary Display

This page will provide a one-page summary of critical mission parameters. The parameters will be changed as required for the various mission phases.

The display will provide, in one place, a summary of TBD critical parameters during a given phase of the mission. It will be selected by depressing the "PAGE SELECT" key, followed by a two letter mnemonic. The first letter will denote the Mission Parameters Summary display, and the second letter will identify the mission phase that begins at one of the 20 reset points provided. As the mission progresses, and different parameters become important, the items on the display page will be changed accordingly.

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The format of the display will be as follows: each line will contain the name of the parameter, its value, and the units in which the value is expressed. Since this will be an information only display, no line identifiers will be necessary.

#### 4.3.1.1.1.9 Interface Data Stream and Telemetry Monitoring

This display will permit the values of any interface data stream telemetry subsystem parameters to be monitored. Telemetry faults can be inserted into any channel and both faulted and true values can be monitored. The CRT pages used for interface data stream will be organized as follows:

- a. Uplink Command Input
- b. Uplink Command Summary
- c. Telemetry Monitoring
- d. Telemetry Malfunction Insertion

#### 4.3.1.1.1.9.1 Uplink Command Input Page (UCIP)

This page will provide the capability for an instructor to insert uplink commands into the training exercise while the simulator is running independently. The command entries into the CRT will be designed in such a manner to be compatible with the mission uplink command documentation - i.e., the decimal, octal or alphanumeric classification system used by NR/NASA to catalogue the commands will be used by the instructor in the operation of this page to identify the commands to be inserted. The page will be formatted in such a manner that all entries required for the various types

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of commands are displayed on the page are line selectable. The format units, and number of characters required for each entry will also be defined in the display format.

The last command entered for each type command will be displayed in the input field. This display will appear on all UCI pages which are being displayed on CRT's regardless of the one from which the command originated.

An error message will be generated for illegal entries and remain for a period of ten seconds.

An override capability will be provided to enable commands from the IOS to be processed regardless of the power configuration and/or signal strengths. The instructor will be able to select or cancel the override by line input. Incorrect or garbled commands will be displayed in a different format, e.g., hexadecimal.

#### 4.3.1.1.1.9.2 Uplink Command Summary Page

A command summary page will be provided which will display for each command entered during a training session the following data:

- a. The code name for the command
- b. Status of the command (e.g., executed, ignored, in-process)
- c. The vehicle uplink system, if redundant or multiple units are on-board, to which the command was addressed.



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d. Originator of the command (MCC, UCIP or any other system capable of inserting uplink commands)

e. The GMT that the command was received in the simulated vehicle.

Incorrect or garbled commands will be displayed in a different code format, e.g., hexadecimal.

All commands will be recorded and available for display on the Uplink Command Summary page regardless of whether the page is active on the CRT at the time the command(s) were entered.

The commands recorded will be limited to those commands which were introduced while the Uplink Command Summary page was actively being displayed on a CRT.

#### 4.3.1.1.1.9.3 Telemetry Monitoring Page

Sequential pages will be provided which will display and monitor all telemetry parameters organized by SSV systems. The telemetry data displayed will repeat the parameter values which are being transmitted to the down-link equipment by the simulated vehicle system programs as modified by the malfunctions inserted in the bit stream pattern through the Telemetry Malfunction Page (TMAL). The parameters will be identified by their TM number and descriptive engineering terminology. The values of analog parameters will be displayed in terms of the engineering units used by the simulator programs, i.e., degrees -Rankine volts, amps, pounds per square inch, etc. The values of discrete parameters may be displayed as on/off, 1 or 0, primary or secondary, etc.

4.3.1.1.1.9.4 Telemetry Malfunction Insertion Page

This page will enable the instructor to insert up to TBD malfunctions into the telemetry down-link data. The page will be formatted in such a manner, that each malfunction entered is tabulated in the order of insertion, and the following data associated with each malfunction measurement is displayed.

- a. Telemetry measurement number
- b. Actual value (in engineering units)
- c. Failed value
- d. Type of malfunction
- e. Malfunction value

The types of malfunctions which may be entered are as follows:

- a. Static integer/discrete
- b. Static bit pattern
- c. Drift malfunction
- d. Offset Malfunction
- e. Fixed value malfunction

The instructor entry operations will be designed so that the allowable and required entries are annotated on the scratch pad line. Error messages will be provided to inform the instructor of illegal operations.

#### 4.3.1.1.1.10 Enroute and Approach Display

The enroute and approach display will provide the following types of horizontal and/or vertical profile flight paths depending on the mode of operation:

Enroute Display

Approach Display

Demonstration Maneuver Display

The display will automatically switch to or from the approach mode when the vehicle position crosses a predetermined boundary for a selected approach area. The display will portray a solid line plot denoting the programmed mission or maneuver and a dashed line will represent the vehicle's path with an aircraft symbol representing the trainee's instantaneous position.

##### 4.3.1.1.1.10.1 Enroute Mode

The enroute mode will provide the instructor with a graphic presentation of the vehicle's flight path in relation to the desired flight path. This graphic presentation will be provided for missions involving space operation as well as atmospheric (ferry) flights. For space operation, the display will present the actual orbit versus the desired orbit of the vehicle. During the rendezvous phase of the mission, the display will provide the instructor with a graphic representation of the relative position of the target and the SSV together with the required parameters to effect a rendezvous.

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For ferry missions, the instructor will be presented a graphic display of the vehicle's ground track compared with the desired ground track. The display will provide a graphic representation, in terms of circles, call letters and channel or frequency of all surface facilities within the area of display.

The enroute mode will operate at continuously variable scales from 1 inch equals 10 nautical miles to 1 inch equals 50 nautical miles as selected from the instructor's control panel. The control will be graduated in 0.1 nautical mile increments and incorporates a positive lock to prevent inadvertant movement.

#### 4.3.1.1.1.10.2 Approach Mode

The approach mode will present a magnified display of the course flown in the approach area with respect to a simulated navigation facility normally located at the center of the chart. The display can then be selected:

- a. Manually by setting in the identification code of the surface facility on the "AIRPORT CHART SELECT" and by depressing the "APPROACH" switch light on the instructor's console.
- b. Automatically, by the simulated aircraft approaching within 30 nautical miles range of the tuned surface facility. As the 30 nautical mile range is exceeded, the display will automatically switch to the previous enroute display.

In the approach mode, the provision will be made to

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vary the scale of the display from 1 inch equals 0.2 nautical miles to 1 inch equals 10 nautical miles as selected by the instructor from his control panel. The control will be graduated in 0.1 mile increments and incorporate a positive lock to prevent inadvertent movement. The simulated facility will be located at the center of the display together with the station call letters and channel or frequency. Dotted lines, aircraft symbols and solid lines will be displayed as described in the enroute display.

As the vehicle approaches to within ten nautical miles from the airport, the display is automatically switched to a terminal mode. In this mode, a split screen display is presented. The upper display will provide an elevation versus range to touchdown point along an axis representing ten miles in length; the lower display presents azimuth versus range to the touchdown point. The displayed runway heading and glideslope will be defined by the surface facility selected by the instructor. This display is used in conjunction with the ILS/GCA display located on the instructor's console. The latter display provides the instructor with a more precise indication of the trainee's deviations and would be used for supplying GCA instructions associated with the terminal phase of a ferry mission.

#### 4.3.1.1.1.10.3 Demonstration Maneuver Display

When a demonstration maneuver is selected, the mission display will automatically display the flight path of the preprogrammed

[The page contains extremely faint, illegible text, likely bleed-through from the reverse side. The text is organized into several paragraphs, with some lines appearing as bulleted lists. Due to the low contrast, specific words and sentences cannot be transcribed.]



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maneuver. Two separate plots will be provided, one for the horizontal projection of the maneuver and one for the vertical projection of the maneuver. As in the previous displays, the programmed maneuver will be displayed as a solid line and dotted lines with an aircraft symbol will depict the trainee's position.

#### 4.3.1.1.1.11 Systems Schematic Displays

Schematic displays will be provided of the vehicle's systems. These displays will be in sufficient detail for the instructor to analyze malfunctions which have been inserted into the training exercise. In addition, the display will also provide a visual aid for instructional purposes.

To call up Systems Schematic Displays, the instructor will press the "PAGE SELECT" key followed by the appropriate mnemonic for systems schematic. This action will display an index of the available systems schematics and the mnemonic associated with each system schematic. Inserting the appropriate mnemonic and pressing the "PAGE SELECT" key will cause the selected system schematic to be displayed. The visual monitor TV system will be used for the display of system schematics.

#### 4.3.1.1.1.12 Programmed Demonstration Displays

These displays will contain a number of preprogrammed displays associated with the SSV missions. In this mode, the simulator will fly the selected maneuver in an ideal manner. The system will provide an additional submode in which the trainee can fly the same

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maneuver and be compared with the ideal demonstration. During the demonstration, the appropriate controls and indicators will be driven as required to execute the maneuver. For each demonstration maneuver, data stored in the computer will define:

- a. Initial conditions
- b. Demand parameter values for each part of a demonstration maneuver
- c. Demand rates of change for each part of a demonstration maneuver
- d. Parameter and value which will define termination of a demonstration maneuver.

To select a demonstration maneuver, the instructor will press the "PAGE SELECT" key and the mnemonic which identifies the Programmed Demonstration. Activation of these keys will cause the index of Programmed Demonstrations to be displayed in addition to the mnemonic which identifies the demonstration. By inserting the appropriate mnemonic and pressing the "PAGE SELECT" key will cause the selected demonstration to be presented on the display. Activation of the "DEMO" switch light located on the instructor's console will cause the simulator to commence the demonstration. (Reference 4.3.1.1.3.6.)

The instructor will be provided the option of retaining the demonstration for future critique purposes or erasing the demon-



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stration. Upon command from the instructor, through the scratch pad line of the CRT, one of the following functions will be executed:

- a. Erase the last demonstration
- b. Erase the entire tape
- c. Transfer the demonstration for playback purposes

On the lower portion of the CRT, just above the scratch pad line, intelligence will be provided to inform the instructor of: (1) recording time remaining (eight hours are available), and (2) the number of segments recorded. This section of the CRT will contain the necessary space to inform the instructor of any condition existing in the vehicle's configuration which would be unsafe for the next segment of the training exercise. As an example, if, in the demonstration the speed brakes were extended and the next segment of the training exercise required that the speed brakes be retracted, a warning would be displayed on the CRT: SPEED BRAKES EXTENDED. The warning would blink to attract the attention of the instructor.

Playback of a trainee executed maneuver would be commanded through the scratch pad line of this CRT page. The demonstration would be identified through the recorded segment number which would be entered through the keyboard. The playback would commence when the "PLAYBACK" switch on the instructor's console was depressed.

#### 4.3.1.1.1.13 Training Exercise Display

This display will provide the instructor with a chronological listing of events which comprise a training exercise. A

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sufficient number of training exercises will be provided with the delivery of the simulator to demonstrate this feature to the customer. In addition to providing a chronological listing of events, the display shall contain parameters and parameter tolerances which should be monitored by the instructor and any special instructions required. This may contain the mnemonics of applicable CRT page(s) for that event. An example of the display format is as follows:

TC	LOS			MET 024:56:12 GMT 131:12:34
TRANG	EX	XX		
<u>MET</u>		<u>EVENT</u>	<u>MONITOR</u>	<u>REMARKS</u>

To select a training exercise, the instructor will press the "PAGE SELECT" key and the mnemonic which identifies this display. This will call up the Training Exercise Display Index, which will indicate the training exercises and the mnemonic associated with each exercise displayed on the index page. By inserting the desired exercise mnemonic and pressing the "PAGE SELECT" key, the selected training exercise will be displayed. The instructor will be provided the capability of making changes in the training exercise during the exercise, through corrections made on the scratch pad line of the display.

The preprogramming software will enable the instructor to accomplish the following functions:

- a. Determine the time in the mission when an event will occur.
- b. Describe the event

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c. If desired, specify any malfunction that should be automatically inserted during any of the tasks in the training exercise.

d. Identify those parameters to be monitored during a mission event.

e. Identify those demonstrations to be used during the training exercise and specify when they should be replayed.

f. Specify standards or criteria for any simulator variable profile on any of the training tasks.

g. Monitor, display and record any performance information that is resident in the computer.

#### 4.3.1.1.1.14 Performance Monitoring Display

This display will provide the instructor with a tabular listing of all information relative to out of tolerance parameters during a mission. The Performance Monitoring Display will contain the following information:

a. Names of all parameters on which tolerances have been exceeded during the current mission. The in-tolerance parameters are excluded to reduce clutter.

b. Allowable tolerance. This gives meaning to the presence of the parameter being presented.

c. Percentage of time out of tolerance. This parameter was chosen, rather than other time-based measures such as RMS deviation, average absolute deviation, etc., as being more meaningful to the instructor and trainee.

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d. Maximum deviation and time of occurrence. These data will highlight that portion of the mission most critical from an instructional viewpoint, in a manner for the instructor and trainee to interpret.

An example of the display format is:

M	LOS	MET 024:56:12	GMT 131:12:34
<u>PARAMETER</u>	<u>TOLERANCE</u>	<u>% TIME OUT</u>	<u>MAXIMUM DEV. TIME</u>

For preprogrammed missions, the performance monitoring parameters will be selected as part of the preprogrammed requirements. The instructor will also be provided the capability of monitoring parameters on-line. Parameters requested on-line will be categorized by mission phase and system for the convenience of the instructor. Selection of the Performance Monitoring Display through the keyboard will present a Performance Monitoring Display Index to the instructor. For a preprogrammed mission, the index will provide the instructor with an index of the Performance Monitoring Display pages categorized by mission phase. For on-line request, the index will be categorized by mission phase, as well as, system. The index will provide the instructor with the mnemonic of the particular page desired. Insertion of the mnemonic into the keyboard and pressing the "PAGE SELECT" key on the special function keyboard will cause the Performance Monitoring Display page to be presented to the instructor. For an on-line request, the instructor will be required to identify those parameters he wishes to display from those available for the mission phase, or system selected. The

selection of parameters to be displayed will be through the scratch pad line of the CRT by the identifying mnemonic.

Upon command from the instructor, the computer will provide a hard copy of the Performance Monitoring Display. To select a printout, the instructor key the following instructions on the scratch pad line:

- a. the mnemonic assigned to the printout request
- b. a number (5, 30, 1, 2, corresponding to the printout rate desired)
- c. a mnemonic assigned to initiate the recording

Upon completion of the above sequence, the printouts will be made every 5 seconds, every 30 seconds, every minute or every two minutes. To deactivate the printout, the instructor inserts into the scratch pad a mnemonic designated to stop the printout.

To demonstrate the on-line request capabilities of the system, the contractor will deliver the Performance Monitoring Display pages for the Launch, on-orbit, and entry mission phases, and the Environmental Control System. For preprogrammed missions, the Performance Monitoring Display pages associated with the deliverable preprogrammed missions will be provided.

4.3.1.1.1.15 External Environment

This page will contain a listing of the following environmental parameters:

- a. Wind direction and speed
- b. Altimeter setting
- c. Outside air temperature
- d. Rough air intensity
- e. Cloud base and top
- f. Visibility

To call up this page, the instructor will press the "PAGE SELECT" key and the mnemonic identifying the External Environment page. To insert an environmental condition, the line will be selected by depressing the "LINE SELECT" key and the line identifier. This action will cause the selected line to be copied on the scratch pad line of the CRT. The cursor will appear in the next space after the environmental parameter. The instructor types in the value of the parameter he wishes to enter. After verifying his entry, the instructor depresses the "INSERT" key which will: (1) insert the parameter value into the system, (2) place the parameter value after the appropriate parameter on the CRT page, and (3) erase the scratch pad.

To change an environmental value already in the simulator, the line will be selected as before. The cursor will appear under the first number of the present value. The instructor will type over the

previously inserted value with the new value he wishes to insert.

Verification and insertion will be as described above.

#### 4.3.1.1.1.15.1 Wind Direction and Speed

It will be possible for the instructor to introduce any wind speed from 0 to 200 knots and any wind direction through 360 degrees. The wind velocity applied will affect the course flown and will produce a correct drift angle and ground speed. Takeoff characteristics, aerodynamic characteristics, and build-up/drop-off rate for airspeed will properly reflect the aircraft performance when the aircraft is subject to the same environment.

#### 4.3.1.1.1.15.2 Altimeter Setting

The instructor will be able to adjust the altitude system to reflect any barometric pressure setting value from 28 through 32 inches of mercury in increments of 0.01 inch. Adjustment of the altimeter setting control will affect the indicated altitude according to standard pressure altitude relationship charts.

#### 4.3.1.1.1.15.3 Outside Air Temperature

The capability to vary outside air temperature from  $-50^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$  will be provided to the instructor. Variations from normal will appropriately affect engine thrust and takeoff characteristics. Installation and compressibility errors will be included.

#### 4.3.1.1.1.15.4 Rough Air Intensity

The instructor will be able to control the intensity of

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simulated rough air conditions. Rough air will be entered through numerical values ranging from 0 (calm) through 10 (intense) in single digits. The effects of rough air introduced will appropriately be reflected in affecting instruments, controls, visual and motion systems. The rough air control will be functional at all airspeeds associated with atmospheric flight.

4.3.1.1.1.15.5 Cloud Base and Top

The instructor will be provided the capability of determining the base of the cloud layer, and the thickness of the layer, which will be reflected in the visual scene. The cloud layer base will be variable from 100 ft. to 50,000 ft. The tops of the cloud layer will be varied from 2000 ft. to 60,000 ft.

4.3.1.1.1.15.6 Visibility

The instructor will be able to introduce visibility into the visual scene from the IOS. The instructor may be able to vary the visibility from 0 nautical miles to 55 nautical miles in any increment.

4.3.1.1.1.16 Simulator Reset

The system will permit the problem to be easily started at one of the 20 reset points, a safe store point, or a write-reset point using controls located on the Operate Control Panel. The initial conditions for the start of simulator operation can be set in four ways:

- a. To one of the 20 reset points stored in the computer.

One of these reset points would be for the beginning of the mission.



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b. At any of the "SAFE STORE" points previously selected by using the "SAFE STORE" switch.

c. At any one of the "WRITE-RESET" points stored in the computer.

d. In "STEP-AHEAD" mode which moves the simulator in either direction a preselected increment of time at a rapid rate.

To set or reset the simulator for the start of operation from one of the 20 reset points, from a safe store point, or from a write-reset point, the instructor will first call up the Simulator Reset page by depressing the "RESET" switch light on the Operate Control panel. The display on this page will contain the following lines, each with an identifier:

- a. Twenty lines with the name of 20 reset points
- b. One line labeled "SAFE STORE"
- c. One line labeled "WRITE-RESET"

To reset the simulator, the appropriate line will be selected, and duplicated on the scratch pad line, by depressing the "LINE SELECT" and line identifier keys.

For resetting to one of the 20 reset points, the "INSERT" key will then be depressed, completing the needed action. For resetting to one of the points previously selected by the time of depression of the "WRITE-RESET" switch, the reference number of that write-reset point, assigned by the computer must be inserted; this will be done by typing it in on the scratch pad line in an appropriately marked space.

For "SAFE STORE", a mission elapsed time must be inserted before the "INSERT" key is depressed, by typing the desired time in appropriately marked spaces on the scratch pad line.

#### 4.3.1.1.1.17 Simulator Status

This page will assist the instructor or operator in performing a "morning readiness check" of the simulator. This program will enable the operating personnel to determine if the simulator is ready for operation. The check will utilize automatic sequencing through a series of standard static outputs utilizing the normal iteration rate of the simulator program. These tests will enable the operator to visually ascertain that the subsystems - visual, DCE, computer and sound - are operating properly.

To select this function, the instructor/operator will depress the "PAGE SELECT" key, and the appropriate keys associated with the mnemonic identifying the Simulator Status page. Insertion of these data will cause the computer to step through the simulator diagnostic program incrementally. The data provided on the CRT page will permit the instructor/operator to visually verify the desired output at each step. The program will require approximately 30 minutes of running time.

#### 4.3.1.1.2 Dedicated Displays

The following instruments will be located on the upper canted sector of the center portion of the IOS. The instruments will be grouped in a configuration similar to the arrangement on the vehicle's

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instrument panel. The section of the console reserved for the dedicated instruments is divided between the two instructor positions.

- a. Caution and Warning Indicators
- b. Monitor, Center CRT
- c. Monitor, Left-Center CRT
- d. Flight Director Attitude Indicator (Commander)
- e. Vertical Speed Indicator (Commander)
- f. Barometric Pressure Altimeter (Commander)
- g. Airspeed/Mach Number Indicator (Commander)
- h. Acceleration Indicator (Commander)
- i. Horizontal Situation Indicator (Commander)
- j. Elapsed Time Meter (Commander)
- k. Gimbal Position Indicator
- l. Monitor, Right CRT
- m. Monitor, Right-Center CRT
- n. Flight Director Attitude Indicator (Pilot)
- o. Vertical Speed Indicator (Pilot)
- p. Barometric Pressure Altimeter (Pilot)
- q. Airspeed/Mach Number Indicator (Pilot)
- r. Radar Altimeter
- s. Acceleration Indicator (Pilot)
- t. Horizontal Situation Indicator (Pilot)
- u. True Airspeed/Static Air Temperature Indicator
- v. Elapsed Time Meter (Pilot)

w. Rudder Position Indicator

x. Elevon Position Indicator

The above repeater instruments located at the IOS will accurately duplicate the readings or indications of their counterpart located in the crew cabin.

#### 4.3.1.1.3 Instructor Station Controls

The instructor will be provided controls at his console for those functions not accomplished through the CRT display system. Since the IOS is designed to provide the flexibility of one or two instructor operation depending on the training exercise, some control panels are duplicated at the Commander and Pilot instructor station. Control panels which are conveniently accessible to both instructors are not repeated. Control panels at both instructor locations are arranged so that those most frequently used are conveniently located for efficient operation. The following panels are located on the IOS. The number following the panel name indicates the number of panels provided.

- a. Simulator Status (1)
- b. Operate Control (1)
- c. Hand Controller Indicator (2)
- d. In-flight Refueling (2)
- e. IFF Transponder (2)
- f. Communications Control (2)
- g. Lighting/Sound Control (2)
- h. Graphic Control (2)
- i. Monitor Select (2)

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#### 4.3.1.1.3.1 Simulator Status Panel

The Simulator Status Panel provides a visual indication to the instructor of the status of the simulator and its associated sub-systems. (Reference Figure 4.3-2 ). This panel is also located in a central location on the IOS console to facilitate convenient access and ease of operation by either instructor. The panel is comprised of two sections. One section contains indicators denoting the status of the visual system; the other section contains indicators which present the status of power, DCE, computer, and motion systems.

##### Visual System Status

"MIP" - Illumination of this indicator denotes that maintenance is in progress on the system.

Thirteen indicators are provided which, when illuminated, denote that the visual scene for that vehicle window is ready to be portrayed. The upper bank of indicators represent the forward cabin windows and are designated as follows:

"LS" - Left side

"LQ" - Left quarter

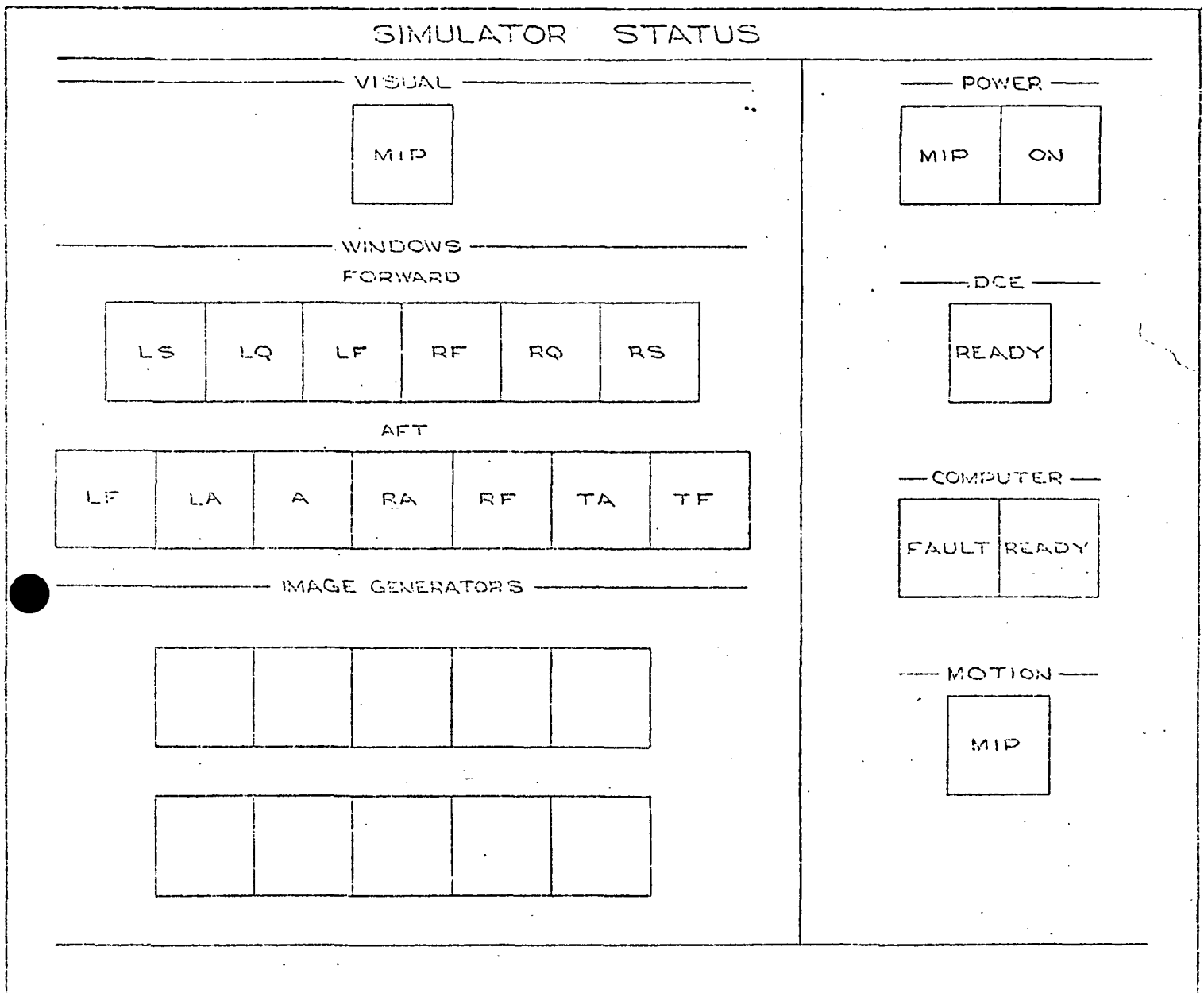
"LF" - Left forward

"RF" - Right forward

"RQ" - Right quarter

"RS" - Right side

The lower bank of indicators depict the cupola windows and are termed as follows:



SIMULATOR STATUS PANEL

FIGURE 4.3-2

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"LF" - Left forward

"LA" - Left aft

"A" - Aft

"RA" - Right aft

"RF" - Right forward

"TA" - Top aft

"TF" - Top forward

The status of the image generators is denoted by ten indicators. When illuminated, the indicator signifies that the appropriate image generator is operational. Since the image generators have not been completely defined at this time, the indicators have not been labeled. Each indicator will represent an individual image generator.

Power System Status

"MIP" - This indicator, when illuminated, represents that maintenance is in progress.

"ON" - When all required power from the main power source is available to the simulator for its operation, this indicator will illuminate.

DCE Status

"READY" - Illumination of this indicator denotes that the DCE unit is tied into the simulator and READY for operation.

Computer Status

"FAULT" - The computer fault light will indicate when a

fault has been detected. When the source of the fault is removed, the light will be extinguished. If the fault is transient, the light will not stay on. The computer fault indicator is only active when the computer is off-line and when not operating in a mission mode.

"READY" - This indicator, when illuminated, signifies that the computer is tied into the simulator and the simulator is READY for operation.

#### Motion Status

"MIP" - This indicator, when illuminated, informs the instructor that maintenance is in progress on the motion system.

#### 4.3.1.1.3.2 Operate Control Panel (Reference Figure 4.3-3)

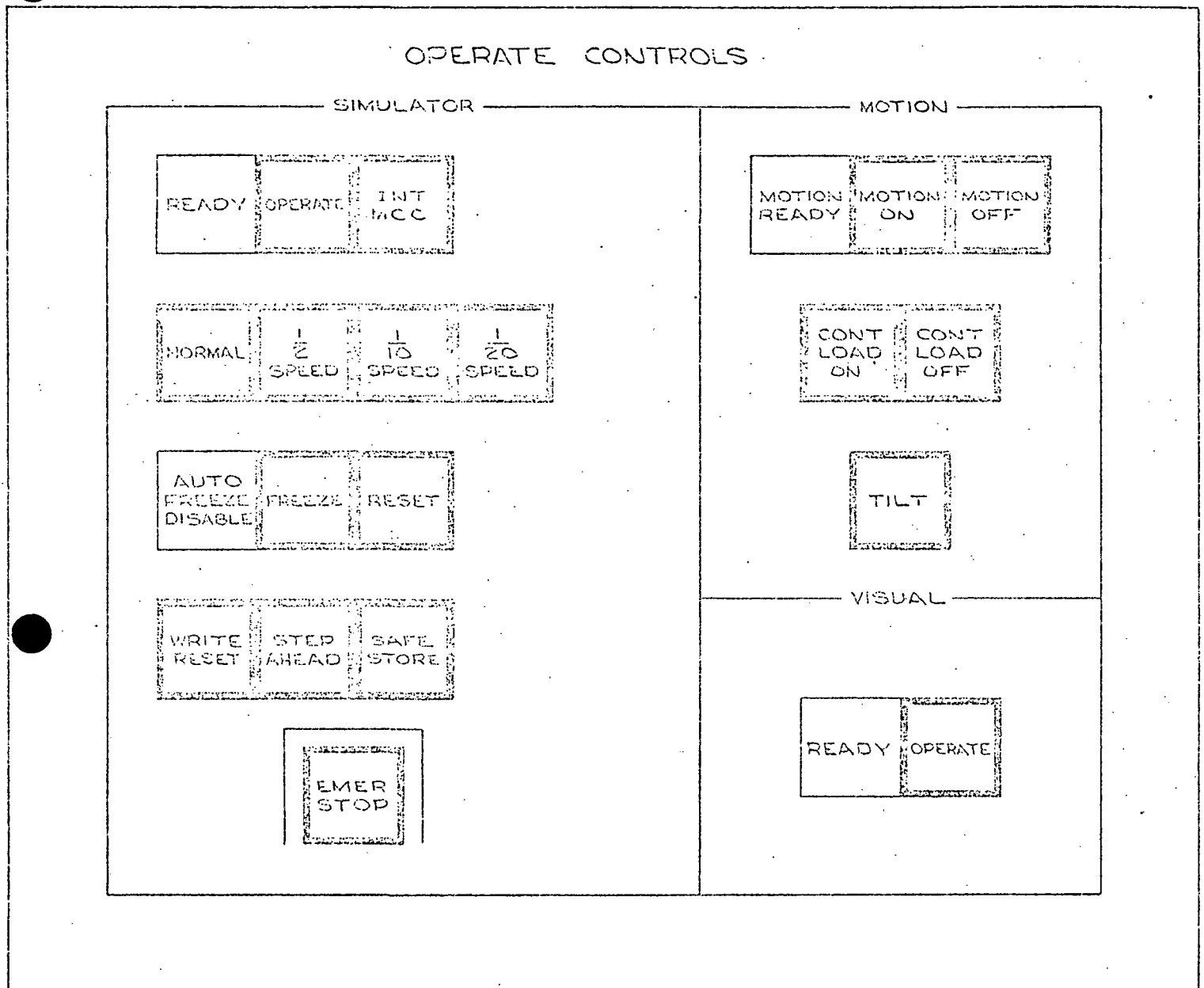
The Operate Control Panel contains all the necessary controls and indicators for the safe operation of the simulator and its subsystems. The panel is located in a central position of the IOS to permit convenient access and ease of operation by either instructor. The panel is divided into three sections each of which contains the controls and indicators peculiar to that simulator function. The sections are titled: SIMULATOR, MOTION and VISUAL.

#### Simulator Control Panel

The following are the indicators and controls located on the Simulator Control Panel and a brief description of their function.

"READY" - This indicator illuminates when power is applied to the simulator and the computer and ancillary equipment are ready for simulator operation.





OPERATE CONTROL PANEL

FIGURE 4.3-3

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"OPERATE" - This switch-light when activated will unfreeze the simulator, causing it to resume operation from the point at which it was frozen.

"INT MCC" - This is a dual action switch-light. When first depressed, the light illuminates and integrates Mission Control Center into the training exercise. A second depression of the switch deactivates this mode, and the light is extinguished.

"NORMAL", " $\frac{1}{2}$  SPEED", "1/10 SPEED", "1/20 SPEED" - These four dual action switch-lights when engaged separately will control the speed at which the training exercise is presented to the trainee. In the NORMAL mode the exercise is presented in real time. The remaining switches permit the instructor to present the training problem in one of the selectable fractional parts of real time as indicated on the switch-light.

"AUTO FREEZE DISABL" - This light is activated, and the simulator is automatically stopped when any of the preselected simulator parameters have been exceeded.

"FREEZE" - Activation of this switch-light causes the computer to enter the freeze mode. In the freeze mode, integration and time varying functions will be held constant.

"RESET" - This switch-light is activated to initialize the simulator to a specific set of initial conditions. The conditions are such that from reset, consumables, switch positions, on-board compu-

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ter modes and trajectory characteristics are representative of the mission planning documentation. Upon activation of the "RESET" switch-light, the reset conditions will be displayed on the CRT and the instructor will have the option of changing parameters through the CRT keyboard. Activation of the simulator from the "RESET" mode will be accomplished through the "INSERT" key located on the special function keyboard.

"WRITE-RESET" - Activation of this switch-light permits the instructor to store, without interrupting the real-time simulation, those values in memory which are required to reinitialize the simulator back to that point.

"STEP-AHEAD" - Activation of the switch-light allows the instructor to advance or retard the training exercise by a pre-selected amount of time. During this mode, the computer will execute the program in faster than real time. The reset point will be selected as follows: Upon depression of the "STEP-AHEAD" switch, the following will be displayed on the scratch pad line of the CRT:

GMT \_\_\_\_\_

The cursor will be positioned after GMT. The instructor will enter the GMT of the position he desires to place the simulator.

"STEP-AHEAD" will be executed when the "INSERT" key is depressed.

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"SAFE STORE" - This switch-light, when activated will cause the simulator to store, once every minute, without interfering with real-time simulation, those values in memory, including all active malfunctions, which are required to subsequently initialize the simulator back to that point. This storage will provide an intermediate point to which a problem can be re-initialized by use of the "RESET" control.

"EMERGENCY STOP" - This red switch-light, when activated, will result in removal of all primary power from the simulator with the exception of 115-volt, 60-hertz utility power. A 3/16-inch red border will surround this switch-light. On the motion-base simulator IOS, this switch-light will also remove all power from the motion system and return the motion platform to the stowed position.

Motion Control Panel. This panel, as described below, applies only to the IOS for the motion-base simulator.

"MOTION READY" - Illumination of this lamp indicates that the motion system is prepared to be activated.

"MOTION ON" - This switch-light is depressed to operate the motion system. This switch is inoperable until the READY light is illuminated.

"MOTION OFF" - This switch-light deactivates the motion system from the simulator and returns the motion platform to the stowed position.

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"CONT LOAD ON", "CONT LOAD OFF" - These two switch-lights control the power to the control loading system.

"TILT" - Activation of this switch-light rotates the motion platform to the launch attitude.

Visual Control Panel

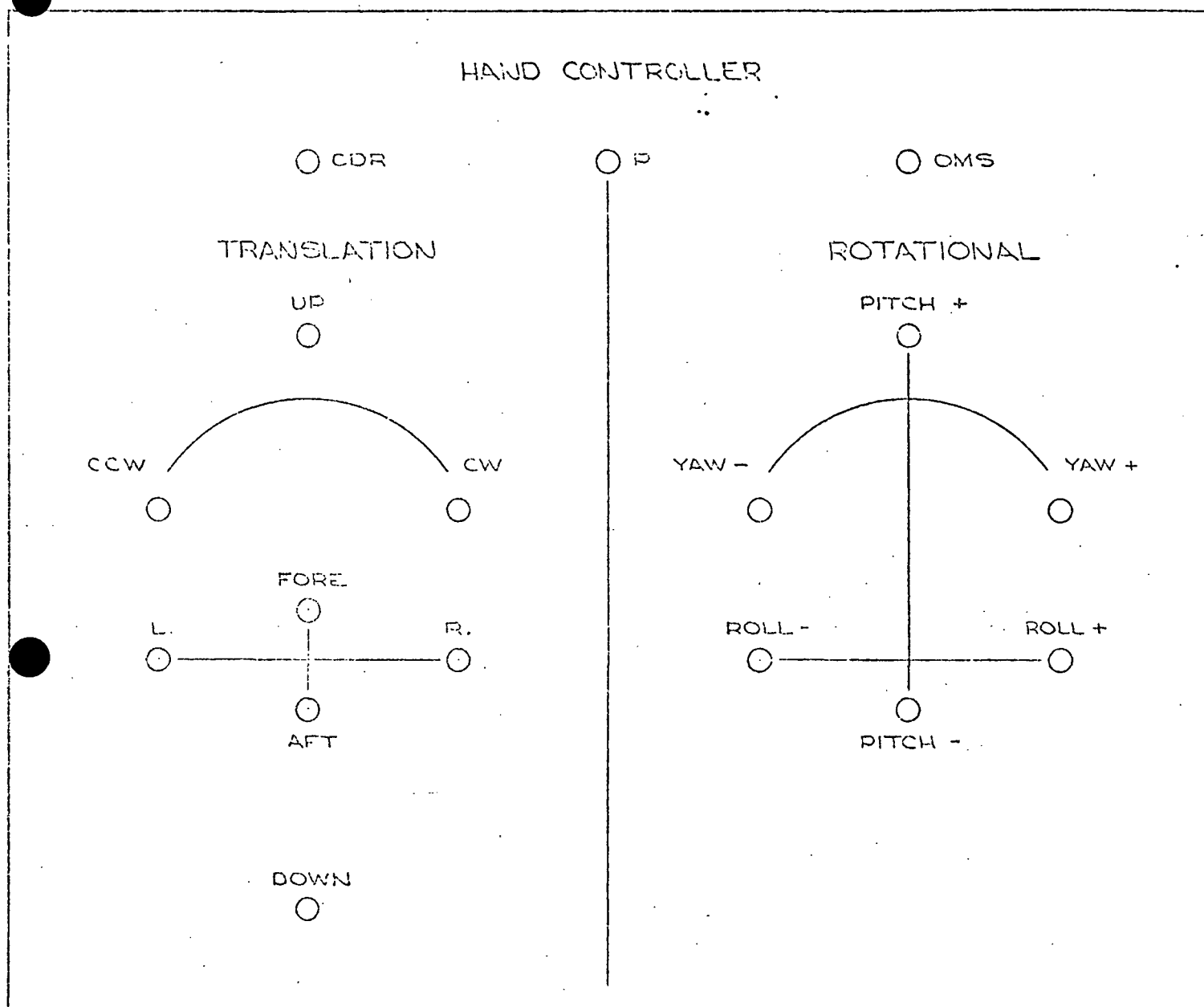
"READY" - This light illuminates when the visual system is available for activation.

"OPERATE" - This dual function switch-light is activated to present the forward station visual scene to the simulator cabin. This switch-light is inactive until the READY light is illuminated. A second depression of this switch deactivates the visual scene.

4.3.1.1.3.3 Hand Controller Indicator Panel

The Hand Controller Indicator consists of a series of tell-tale lights which inform the instructor of hand controller activity (Reference Figure 4.3 -4). Three lights are provided to indicate the location at which the hand controller is being operated: "CDR" - Commander's Station, "P" - Pilot Station, "OMS" - Orbit Maneuvering Station. Eight tell-tale lights provide the following positions of the translational hand controller:

- a. Up
- b. Down
- c. Clockwise
- d. Counterclockwise
- e. Forward
- f. Aft



HAND CONTROLLER INDICATOR PANEL

FIGURE 4.3-4

g. Left

h. Right

Six lights indicate the following directions of the rotational hand controller:

a. Positive Pitch

b. Negative Pitch

c. Positive Yaw

d. Negative Yaw

e. Positive Roll

f. Negative Roll

#### 4.3.1.1.3.4 In-Flight Refueling Panel

In-flight refueling is associated with the Ferry phase of the SSV mission. The in-flight refueling phase of this mission will be simulated to a limited extent. A visual scene for rendezvous and hook-up with the tanker aircraft will not be simulated. However, the effects of on-loading fuel from the tanker will be part of the simulator program (e.g., increase in the fuel quantity gauges for the ABES at a constant rate, change in the vehicle's CG as the fuel load increases). The instructor will be provided an "ON" and an "OFF" switch for controlling the in-flight refueling program. A fuel quantity indicator will also be provided to appraise the instructor of the progress of the refueling operation (Reference Figure 4.3-5).

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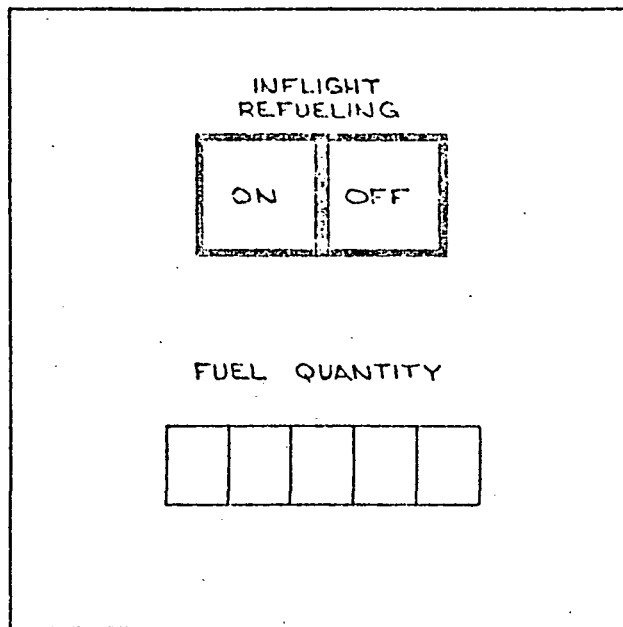
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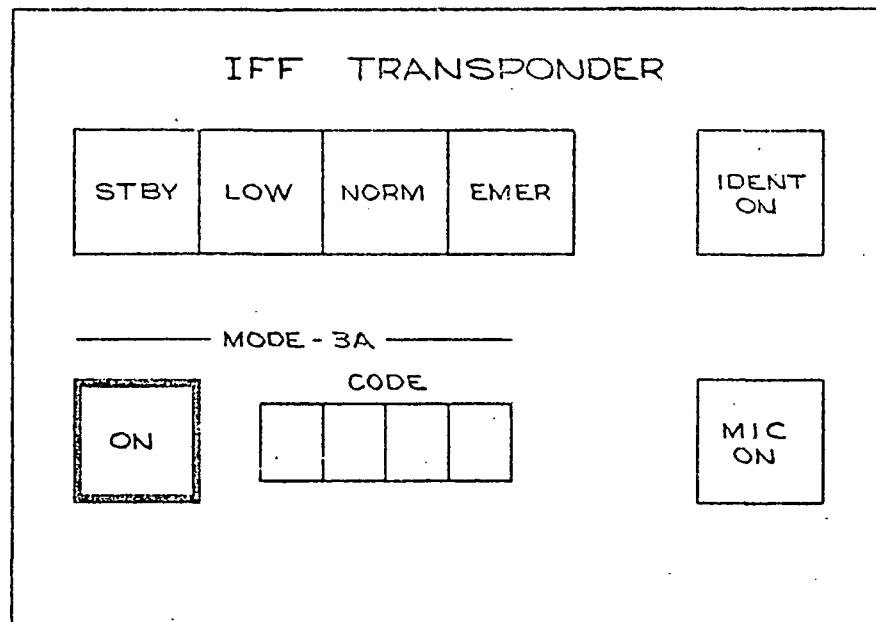
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INFLIGHT REFUELING PANEL

FIGURE 4.3-5



IFF PANEL

FIGURE 4.3-6



#### 4.3.1.1.3.5 IFF Transponder Panel

This panel presents to the instructor the position of switches and the code identifier inserted into the IFF panel in the simulator cabin. (Reference Figure 4.3- 6 ). The following indicators repeat IFF switch positions:

- a. "STBY" - Standby
- b. "LOW" - Low sensitivity
- c. "NORM" - Normal sensitivity
- d. "EMER" - Emergency code activated
- e. "IDENT ON" - Identification switch activated
- f. "ON" - Mode 3A is in operation
- g. "MIC ON" - Indicates that the identification signal is being transmitted through the microphone switch.

The numerical identification code to which the transponder is tuned is read out on the code identifier.

#### 4.3.1.1.3.6 Record/Playback Panel

These controls, in conjunction with the keyboard are used to record the trainee's performance and play it back at a subsequent time (Reference Figure 4.3-7 ). This feature will also permit the instructor to demonstrate a preprogrammed maneuver to the trainee. The following controls are located at the IOS.

"OPERATE" - This switch-light operates in conjunction with the "DEMO" mode. The switch-light, when activated permits the selected demonstration maneuver to commence.

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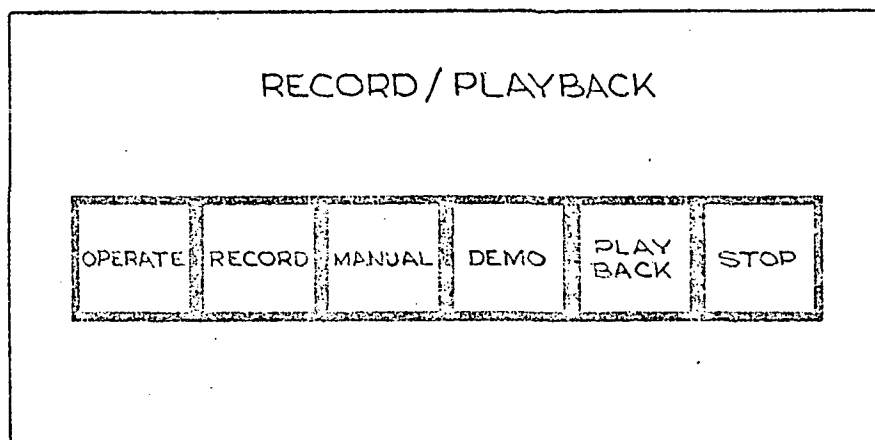
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RECORD/PLAYBACK PANEL

FIGURE 4.3-7

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"RECORD" - Activation of this switch-light permits the system to commence recording, in real-time, the trainee's actions in controlling the simulated vehicle.

"MANUAL" - This selector switch-light provides the instructor with the capability of designating the type of recording desired. Activation of this switch-light allows the instructor to record the real-time performance of the student. This selection switch is used in conjunction with the "RECORD" switch.

"DEMO" - This is a selector switch-light. Activation of the switch permits the instructor to have a preprogrammed maneuver demonstrated to the trainee. Selection of the maneuver is made by the instructor through a Demonstration Index which is displayed on the CRT and designated through the CRT keyboard.

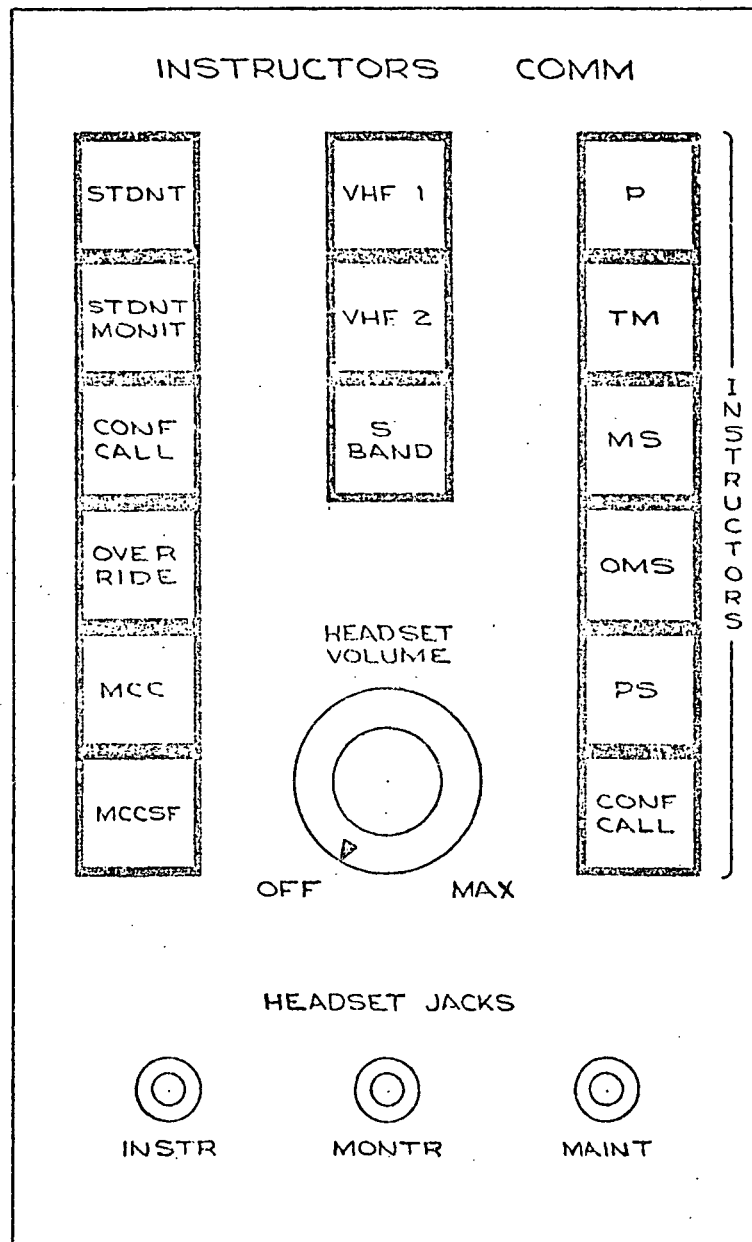
"PLAYBACK" - This switch-light when activated permits the instructor to replay the trainee's recorded performance.

"STOP" - This switch-light deactivates the recording in either the "MANUAL" or "DEMO" mode of operation.

#### 4.3.1.1.3.7 Communications Control Panel

This panel contains the controls necessary for the instructor to communicate with the trainee, other instructors and personnel in support of the training program (Reference Figure 4.3- 8)

"STDT" - This switch-light, when activated, permits communication between the instructor and the trainee.



COMMUNICATIONS PANEL

FIGURE 4.3-8

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"STDT MONIT" - Activation of this switch-light allows the instructor to monitor all communication activity performed by the trainee.

"CONF CALL" - This switch-light provides the instructor with the capability to communicate with all trainees simultaneously.

"OVERRIDE" - This switch-light permits the instructor to talk to the trainee regardless of the station to which he is tuned.

"MCC" - Activation of this switch-light provides a communication network between the instructor and Mission Control Center.

"MCCSF" - This switch, when activated permits communication between the instructor and the Mission Control Center Simulation Facility.

The INSTRUCTOR bank of switches provides a communications network between the instructors. Activation of a switch-light at an IOS would cause the switch-light of the station initiating the call to blink at the station being called. As an example, if the instructor at the Commander's IOS wished to communicate with the Mission Specialist instructor, the Commander instructor would depress the "MS" switch-light at his station. When depressed, the CDR switch-light at the Mission Specialist IOS would begin blinking. When the Mission Specialist instructor depressed the "CDR" switch-light at his station, the light would illuminate steady, and communications could commence between the two stations.

A "CONF CALL" switch-light is provided to permit an instructor to talk to all other instructors at the same time.

"VHF 1", "VHF 2", "S BAND" - These three switch-lights permits the instructor to act in the role of the ground station operator when the appropriate switch-light is depressed.

Headset Jacks - Three headset jacks are provided for the instructor, a monitor, and for maintenance personnel. The maintenance jack permits communications between selected maintenance locations within the simulator complex. This network operates independent of simulator power.

Headset Volume - This control permits the sound intensity of the headset(s) to be varied.

#### 4.3.1.1.3.8 Lighting/Sound Control Panel (Reference Figure 4.3-9)

"VOLUME" - This control permits the instructor to vary the intensity of the vehicle's sounds. The "NORMAL" position is clearly identified.

"SOUND ON" - This dual action switch-light allows the sound system to be activated and deactivated.

"CONSOLE" - This control permits the instructor to vary the intensity of the console lighting.

"INDICATOR" - This control permits the intensity of the indicator lights and switch lights on the instructor panel to be varied.

"L. IND LAMP TEST", "R. IND LAMP TEST" - Activation of

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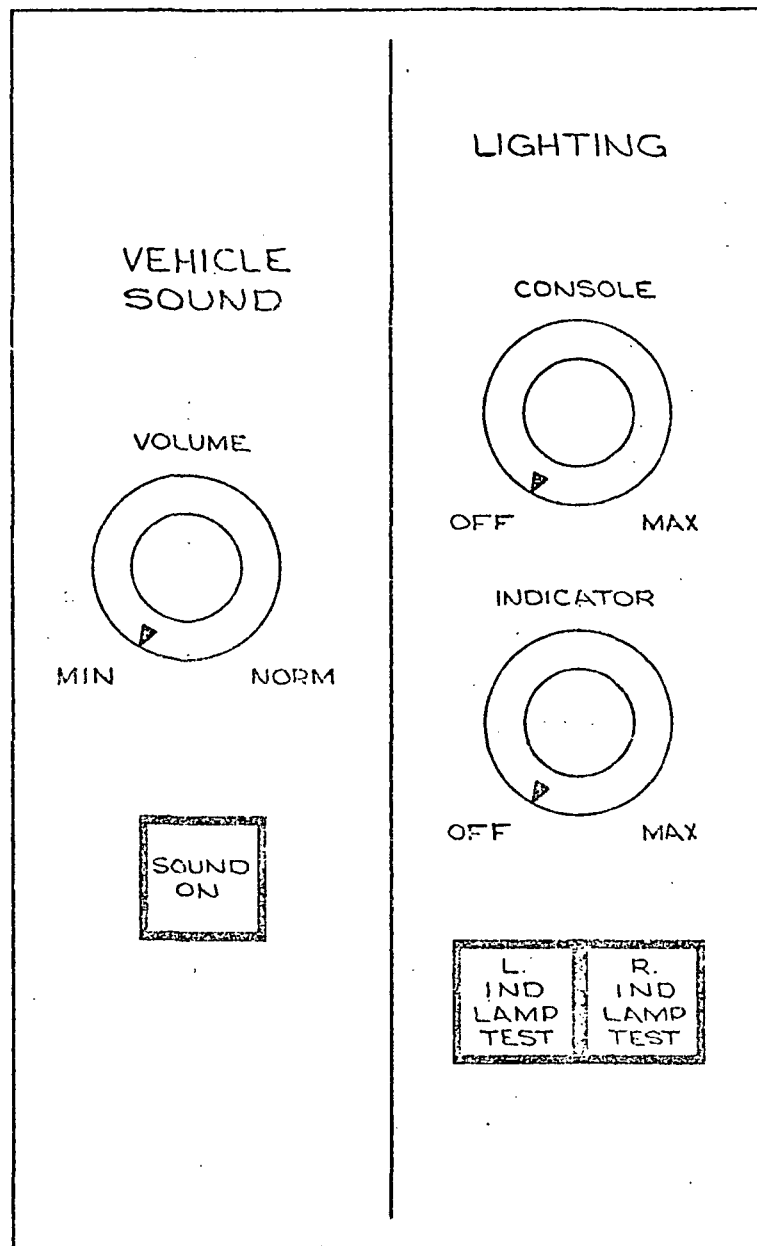
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LIGHTING/SOUND PANEL

FIGURE 4.3-9

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these momentary push button switches will illuminate indicator lamps and switch lamps on the instructor panel. One switch will test the left portion of the console; the other will test the right portion. Burned out lamps can be easily replaced from the front of the panel without special tools.

#### 4.3.1.1.3.9 Graphic Control Panel

This panel provides the instructor with the capability to control the presentation on the graphic display and on the visual monitor (Reference Figure 4.3-10 ). The following is a description of the function of the controls.

"SPATIAL" - This switch-light is used in conjunction with the Spatial Display Rotational Controls. Engagement of this switch is required to activate the rotational controls..

"ENROUTE" - This switch-light, when activated, presents on the graphic display the ground track or orbital track of the aircraft depending on the phase of the mission..

"APPROACH" - Activation of this switch-light presents a magnified display of the course flown in the approach area with respect to a simulated navigation facility.

"LONG AXIS" - This switch-light permits the instructor to rotate the visual scene on the visual monitor around the longitudinal axis of the vehicle.

"VERT AXIS" - Activation of this switch-light allows the instructor to rotate the picture on the visual monitor around the vertical axis of the vehicle.



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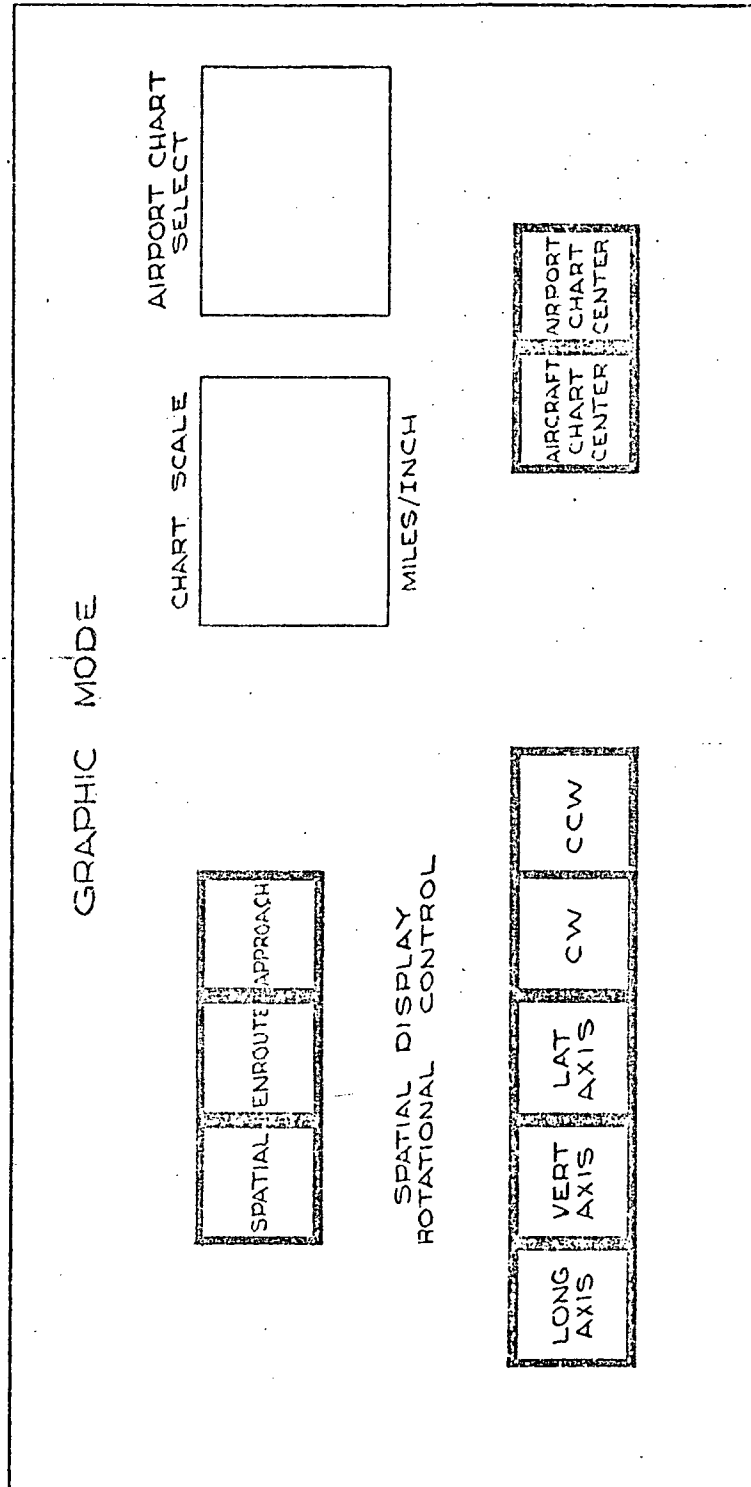
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GRAPHIC MODE PANEL

FIGURE 4.3-10

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"LAT AXIS" - Engaging this switch-light permits the instructor to rotate the visual scene around the lateral axis of the vehicle.

"CW, CCW" - These switches operate in conjunction with the three previous switches. Once the instructor has selected the axis he wishes to rotate about, selection of the "CW" or "CCW" switch determines the direction of rotation. The switch is depressed until the scene has been rotated to the desired attitude.

"CHART SCALE" - This control consists of three thumb wheel knobs by which the instructor can vary the scale of the Enroute and Approach displays. The scale is variable from one inch equals 0.2 nautical mile to one inch equals 50 nautical miles. The scale may be changed in 0.1 nautical mile increments, and incorporates a positive lock to prevent inadvertent movement.

"AIRPORT CHART SELECT" - This control consists of two thumb-wheel knobs which select a preprogrammed airport approach chart to be displayed on the graphic CRT. The number of airport approach charts to be in inventory is TBD.

"AIRCRAFT CHART CENTER" - Activation of this switch-light places the vehicle in the center of the display.

"AIRPORT CHART CENTER" - This switch-light when activated permits the instructor to place the airport in the center of the display.

#### 4.3.1.1.3.10 Monitor Select Panel

This control panel permits the instructor to monitor the visual scene as portrayed to the various crew positions (Reference Figure 4.3- 11). Tell-tale lights illuminate when a visual scene is present in any of the crew position windows. A switch-light is provided for the instructor to select the visual scene he wishes to view on the visual monitor located on his console. The switch-lights are labeled as follows on the instructor's console:

- "LS" - Left side window
- "LQ" - Left quarter window
- "LF" - Left forward window
- "RF" - Right forward window
- "RQ" - Right quarter window
- "RF" - Right Forward window

#### 4.3.1.1.3.11 ILS/GCA Monitor Panel

This panel is used during the approach and landing phase of the Ferry mission when the instructor is acting in the role of the ground controller (Reference Figure 4.3-12 ). The indicators permit a more precise description of the approach and landing parameters than are provided by the graphic display. The indicators on the panel also permits the instructor to monitor ILS approaches. The following is a description of the controls and indicators located on this panel.

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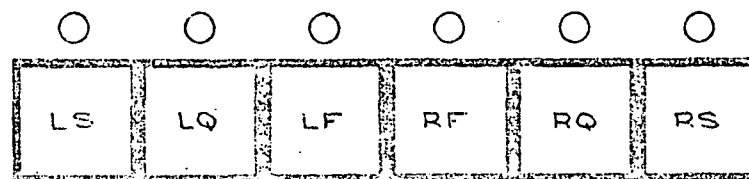
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# MONITOR SELECT



## MONITOR SELECT PANEL

FIGURE 4.3-11

ILS/GCA

GLIDE SLOPE DEVIATION	RANGE NM	HEADING DEG	AIRSPEED K
	[ ] [ ]	[ ] [ ] [ ]	[ ] [ ] [ ]
	LOCALIZER DEVIATION		
	DEG      FT X 100		
	FREQUENCY - MHZ		

ILS/GCA PANEL

FIGURE 4.3-12

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"GLIDE SLOPE DEVIATION" - This indicator presents to the instructor the deviation of the vehicle, in feet, from the planned glide slope.

"LOCALIZER DEVIATION" - Indications on this meter provides the instructor with variations, in degrees, of the vehicle from the localizer course to the runway.

"RANGE, NM" - This indicator provides the instructor with the distance of the vehicle to touchdown. Distance is displayed in miles and tenths.

"HEADING, DEG" - The heading of the vehicle is presented to the instructor on this indicator.

"AIRSPEED K" - During the approach and landing, the vehicle's airspeed is displayed on this indicator in knots.

"DEG", "FT X 100" - Activation of this switch-light provides the instructor with an expanded scale of the "GLIDE SLOPE DEVIATION" AND "LOCALIZER DEVIATION" indicators during the terminal phases of the approach and landing.

"FREQUENCY MHZ" - Five thumb-wheel knobs permit the instructor to select the frequency of the landing aid. Insertion of the frequency into the training problem is commanded through the special function keyboard.

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#### 4.3.1.1.3.12 Speaker Panel

A speaker is provided at the IOS. The panel contains the speaker and the necessary controls for its operation (Reference Figure 4.3- 13 ).

"VOLUME" - This control permits the sound intensity of the speaker to be varied.

"SPKR ON" - Activation of this dual action switch-light causes the signals normally provided through the headsets to be channeled through the speaker.

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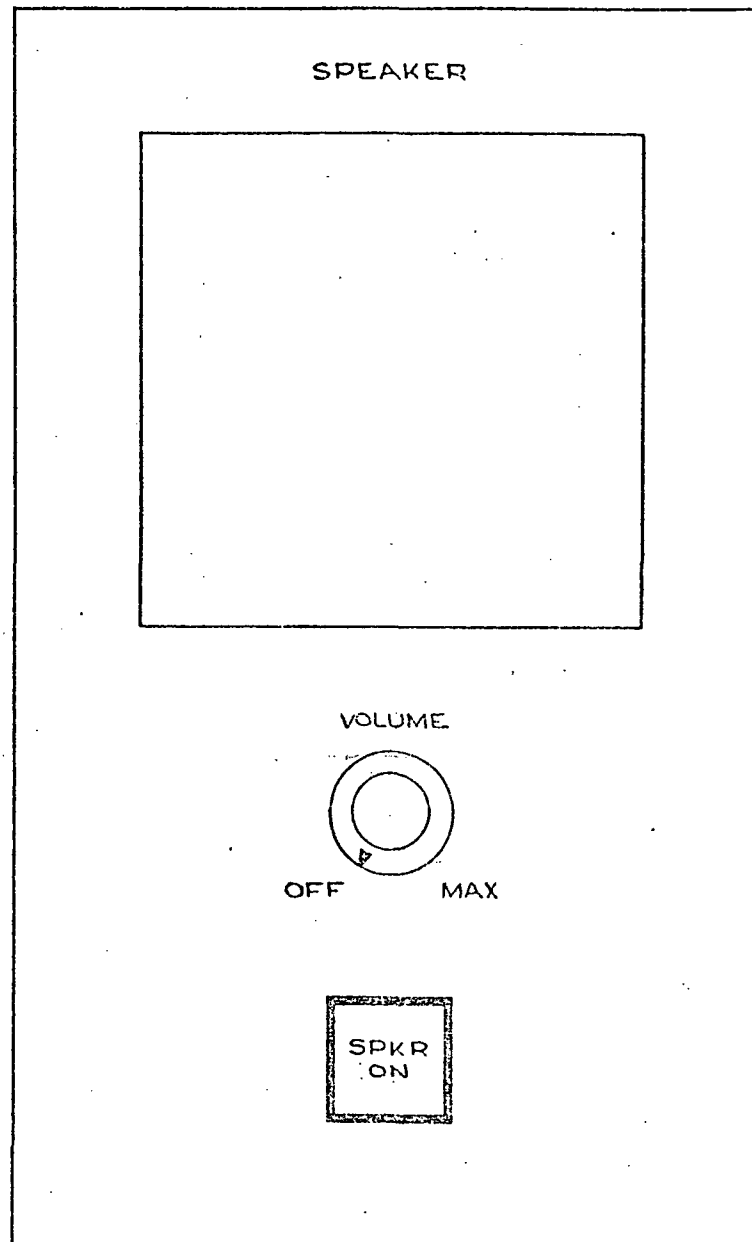
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SPEAKER PANEL

FIGURE 4.3-13



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#### 4.3.2 In-Cockpit Instructor Station (Reference 4.3-14)

Provisions will be made for an instructor station within the crew cabin of the motion-base crew station. This station will be occupied when the Mission and Payload Specialists' seats are not occupied. The instructor seat will be portable and installed prior to the mission requiring an on-board instructor. Fittings will be provided in the simulator to permit the installation and removal of the seat with a minimum effort and within a short time period. The seat will be located in the center of the forward crew cabin, just aft of the center console.

The instructor will be provided with a portable control panel for operating the simulator from this position. The following controls will be available to the instructor:

- a. "READY" light
- b. "OPERATE" switch-light
- c. "INT MCC" switch-light
- d. "RESET" switch-light
- e. Reset Thumbwheel selector
- f. "NORMAL" switch-light
- g. "1/2 SPEED" switch-light
- h. "1/10 SPEED" switch-light
- i. "1/20 SPEED" switch-light
- j. "AUTO FREEZE DISABL" light

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READY	OPERATE	INT MCC	RESET	RESET THUMBWHEEL KNOBS
NORMAL	$\frac{1}{2}$ SPEED	$\frac{1}{10}$ SPEED	$\frac{1}{20}$ SPEED	
AUTO FREEZE DISABL	FREEZE	MOTION READY	MOTION OPERATE	EMER STOP
CONTR LOAD OPERATE	TILT	VIS READY	VIS OPERATE	

IN COCKPIT  
INSTRUCTOR STATION

FIGURE 4.3-14

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- k. "FREEZE" switch-light
- l. "MOTION READY" light
- m. "MOTION OPERATE" switch-light
- n. "CONTR LOAD OPERATE" switch-light
- o. "TILT" switch-light
- p. "VIS READY" light
- q. "VIS OPERATE" switch-light
- r. "EMER STOP" switch-light

A description of the functional operation of these controls is contained in the corresponding paragraphs in 4.3.1.1.3.2 Operate Control Panel. The instructor would be provided a three-position thumb-wheel knob for selecting reset points used in conjunction with the "RESET" switch-light.

While operating from this position, the instructor will utilize the communication controls and headset jack at the Mission Specialist Station.

#### 4.3.3 Telemetry Operator Station

The Telemetry Operator Station serves to incorporate uplink commands and monitoring telemetry data into the training exercise. One Telemetry Operator Station will be provided to service both the fixed-base and motion-base simulators. Although telemetry and interface data may be inputted through any of the IOS's, this station would be utilized during training exercises when the work load at any of the IOS's is too great for the primary instructor to handle. During integrated crew training, exercises and mission rehearsals, the Telemetry Operator Station will be an integral part of the IOS complex.

The Telemetry Operator Station will consist of a CRT, a keyboard unit, and a communications control panel. The station is vertically stacked to conform with the design of the Commander-Operator IOS. The upper segment is canted downward 30 degrees from the vertical, the middle segment is vertical, and the lower section is inclined 45 degrees from the horizontal, and joins the horizontal writing surface. The upper tier contains a blank panel for future growth. The middle tier contains the Operator's CRT, and the lower tier provides space for the communications control panel.

A writing surface, 16 inches deep provides adequate space for reference materials and for writing. The height of the writing shelf above the floor is  $25\frac{1}{2}$  inches (in conformity with MIL-STD-1472 and MSFC-STD-267A) which allows the keyboard unit to be at a comfortable

level, and yet provides ample knee room for the instructor.

#### 4.3.3.1 CRT Display/Keyboard Unit

The CRT display/keyboard unit will provide the Telemetry Station operator with the necessary displays to monitor mission performance, and the required controls for entering all data associated with the telemetry and interface data function. The CRT will be capable of providing both alphanumeric and graphic data.

The display/keyboard unit will operate identically to those described previously in 4.3.1.1.1, and the same keyboard action will be used to select a display or modify a value stored in the computer. The top line of the CRT will always contain the following data:

- a. A one-or two-character display mnemonic identifying the display.
- b. Symbols indicating the ground station in contact with the vehicle; if none are in contact, LOS will be displayed.
- c. Mission elapsed time
- d. Simulated Greenwich mean time

The following CRT pages, identical to those available at the Commander-Pilot IOS, will be provided at the Telemetry Operator Station. The Telemetry operator will be able to call up a page display independent of the action at any other IOS.

- a. Event Time Monitor
- b. Panel Displays

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- c. Energy Management Predictor
- d. Malfunction Insertion and Display
- e. Circuit Breaker Status
- f. Crew Station Setup Verification
- g. Active Malfunctions and Tripped Circuit Breakers
- h. Mission Parameters and Summary Display
- i. Interface Data Stream and Telemetry Monitoring
- j. Enroute and Approach Display
- k. System Schematic Displays
- l. Programmed Demonstration Display
- m. Training Exercise Display
- n. Performance Monitoring Display
- o. External Environment
- p. Simulator Reset
- q. Simulator Status

A description of the above displays and the method by which the displays are called up is as outlined in Sections 4.3.1.1.1.1 through 4.3.1.1.1.16.

A separate CRT is not provided at the Telemetry Operator Station to display information associated with Event Time Monitoring functions. A page will be provided to display chronologically the most recent crew actions and will contain the same data as previously described in 4.3.1.1.1.1.

#### 4.3.3.2 Station Controls

The telemetry operator's station will contain no controls associated with the operation of the simulator. A Communications Control Panel will be provided for necessary communications with the trainee(s), other instructors, and personnel in support of the training exercise. The control panel will be located on the right side of lower tier in a position where it will not interfere with the operator's performance, yet conveniently located for its operation. The following controls are located on the panel (Reference Figure 4.3-15):

"INTRCM" - This switch-light, when activated permits the operator to communicate with any of the crew members through the simulated intercom system.

"STDT MONIT" - Activation of this switch-light allows the operator to monitor all communication activity performed by the trainee.

"CONF CALL" - This switch-light provides the operator with the capability to communicate with all trainees simultaneously.

"OVERRIDE" - This switch-light permits the operator to talk to the trainee regardless of the station to which he is tuned.

"MCC" - Activation of this switch-light provides a communications network between the operator and Mission Control Center.

"MCCSF" - This switch when activated permits communication between the operator and the Mission Control Center Simulation Facility.

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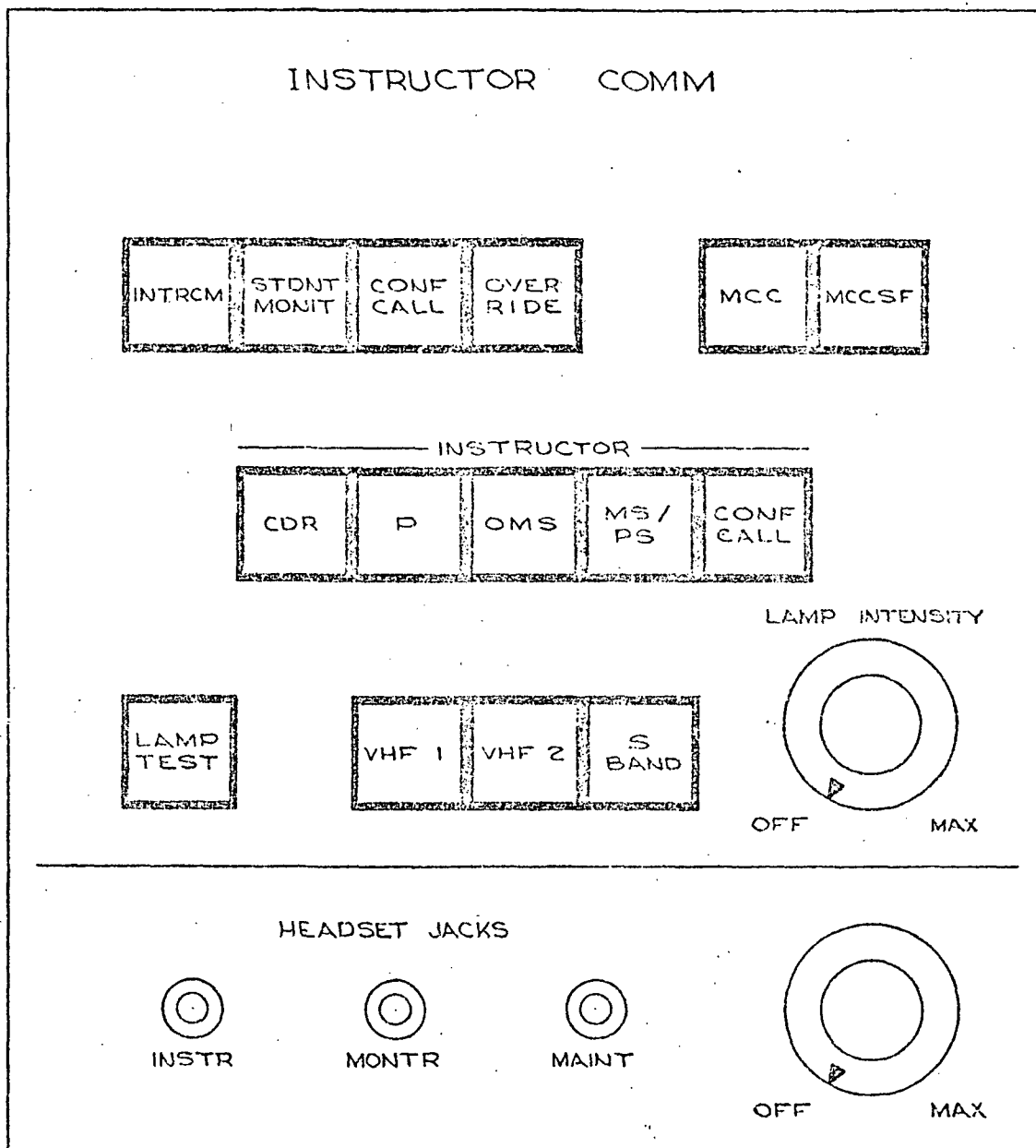
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TELEMETRY OPERATOR

FIGURE 4.3-15



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The "INSTRUCTOR" bank of switches provides a communication network between the instructor-operators. Activation of a switch-light at an IOS would cause the switch-light being called to blink at the station being called. The light would blink until the switch was depressed when communication could be conducted. The "CONF CALL" switch-light permits an instructor to talk to all other instructors at the same time.

"VHF 1", "VHF 2", "S BAND" - These three switch-lights permit the operator to act in the role of the ground station operator when the appropriate switch-light is depressed.

"LAMP TEST" - This momentary switch when depressed will illuminate the lamps in the switch-lights.

"LAMP INTENSITY" - This control permits the brightness of the switch lamps to be varied.

Headset Jacks - Three headset jacks are provided for the operator, a monitor, and for maintenance personnel. The maintenance jack permits communications between selected maintenance locations within the simulator complex. This network operates independent of simulator power.

Headset Volume - This control permits the sound intensity of the headset(s) to be varied.

4.3.4 Layout Mock-Up

A layout of the instructor's area along with the justification for that layout will be provided at the contractor's plant prior to the firm requirements relative to the overall layout. Where major components are duplicated on the console (e.g., CRT displays) only one will be modeled in detail. The model will be as complete as necessary to permit evaluation of the general arrangement and installation of the following equipment.

- a. Location of the IOS's with respect to crew compartment stations.
- b. Instructor-operator flight compartment controls.
- c. Full scale replica of all cabinets and panels including controls and indicators located in the instructor-operator areas.
- d. Instructor chairs
- e. Lighting arrangement
- f. Sample of panel painting and engraving.

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#### 4.3.5 Classroom Terminals

Repeater terminals of the in-cabin CRT's and their associated keyboards will be provided to instruct the trainee in their use. The repeater terminals will be provided for use in a classroom environment. The number of CRT's and keyboard units is TBD. The CRT terminals will also permit the trainee to monitor training exercises conducted in the simulator.

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#### 4.4 Ancillary Equipment

The ancillary equipment consists of the following:

- a) Simulator Power Hardware
- b) Aural Cue System
- c) External Interface Equipment
- d) Simulator Central Timing System
- e) Audio Communications System
- f) Simulator Maintenance Interphone

##### 4.4.1 Simulator Power Hardware

A single double-bay cabinet will be used to control and distribute all 120/208VAC power to the simulator complex. The cabinet will contain sequencing controls, phase warning indicator, emergency stop button, line voltage meter and selector, circuit breakers, and all necessary electronics to control power sequencing.

Two double-bay cabinets will be used to distribute DC power; one for each simulator. The DC cabinets will be identical and will contain power supplies, voltmeters, ammeters, circuit breakers, and distribution busses.

All fused wall disconnects and associated cabling up to the simulator equipment will be supplied by NASA.

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4.4.1.1 277/480V Power (Figure 4.4-1)

The following equipment will be powered by 277/480V, three phase, 60-hertz power. Isolating the heavy motor loads to the 277/480V voltage source will minimize the effects of voltage surges to the rest of the simulator complex, which will operate on 120/208V power.

		KVA	
		<u>Start</u>	<u>Normal Running</u>
Main Hyd. Pump #1	75 HP	109	30
Main Hyd. Pump #2	75 HP	109	30
Control Loading Pump	10 HP	64	9
Boost Pump	5 HP	34	4
Air Compressor	10 HP	64	9
		380 Kva	82 Kva

The power turn-on sequencing will be designed to prevent more than one motor drawing starting current at a time. Maximum turn-on surge will result when the motion pump is turned-on while the air compressor and control loading pump are running; it will be 127 Kva (108 Kw).

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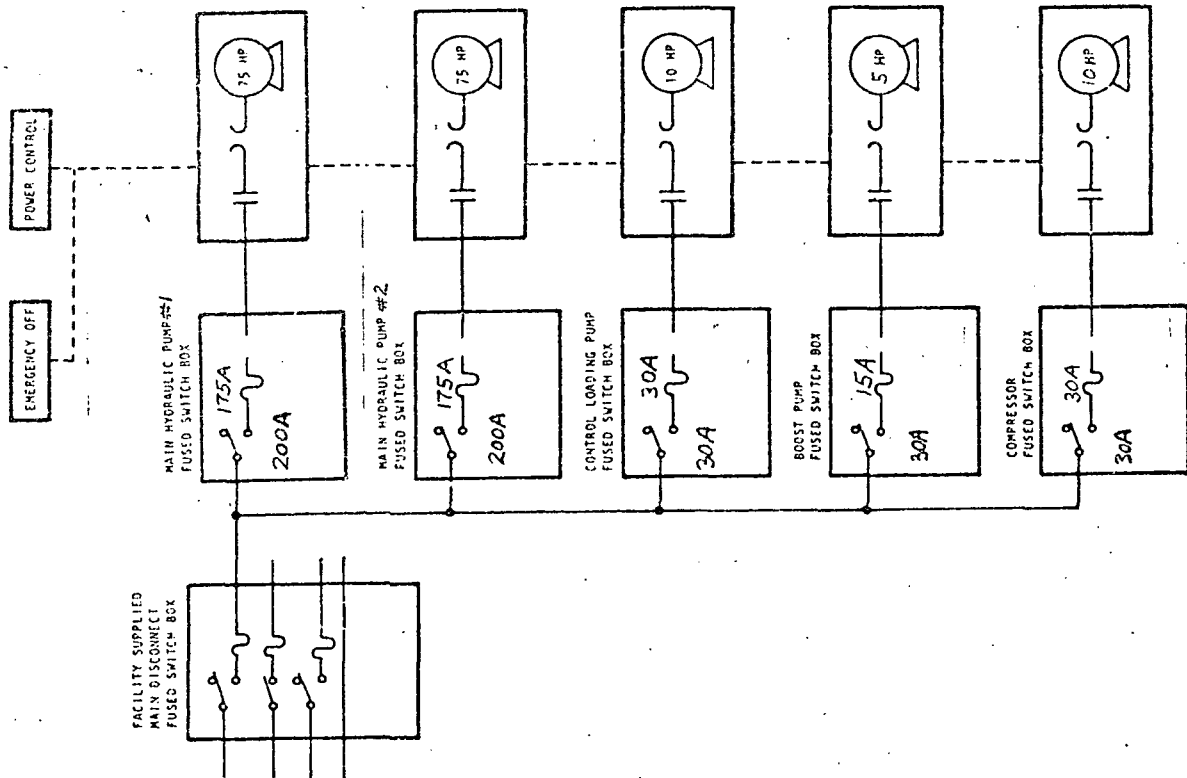
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NOTE: ONLY ONE PHASE SHOWN, TYPICAL

Figure 4.4-1 POWER CIRCUIT (277/480V, 60 HZ)

277/480V  
3 Phase  
60 HZ

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#### 4.4.1.2 Power Distribution & Control (Figure 4.4-2)

The SMS will be designed to operate from a 120/208 volt ( $\pm 10\%$ ), three-phase, four-wire, 60-hertz ( $\pm 5\%$ ) primary power source. The power factor will be 85% and line current unbalance will not exceed  $\pm 7.5\%$  of the average line current.

The facility-supplied main fused disconnect switch will control all power to the simulator. Tripping or throwing the shunt-trip breaker will also shut off all power to the simulator equipment units.

All equipment and circuits will be adequately protected. Protection equipment will consist of circuit breakers, phase warning, and sequence lights. An overtemperature warning circuit, consisting of a warning bell, temperature sensors located in each cabinet, and warning lights to indicate which cabinet is overheated, will be provided. Readily accessible emergency-off switches will be located throughout the complex to disconnect all power to equipment.

##### 4.4.1.2.1 Utility Power System

The utility electrical power circuit will be powered from the main power disconnect box and is operable while the remainder of the simulator power is off. Trouble lights, reel-type recoil lights, instructor station lights, utility power outlets (W-C-596) and the maintenance intercommunication system are powered from this circuit. Utility lighting will be provided in the cockpit area, in the area under the motion platform, and in any other normally dark areas where

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maintenance may be required. Utility light bulbs will be guarded against accidental breakage, and each group of lights will be controlled by an ON-OFF switch.



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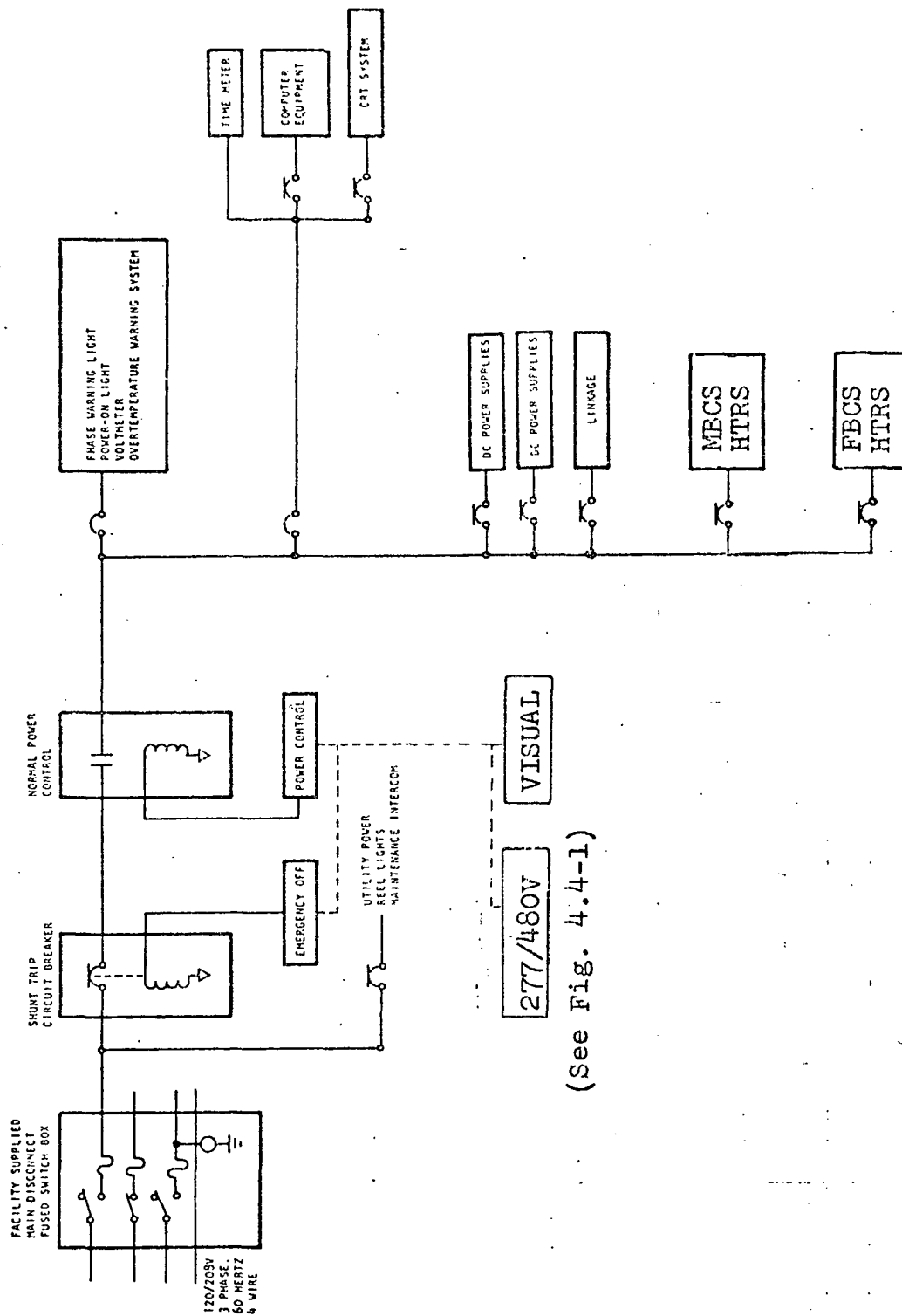
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(See Fig. 4.4-1)

Figure 4.4-2  
MAIN POWER DISTRIBUTION (120/208V, 60 HZ)

#### 4.4.1.3 400 Hz Power Control

NASA supplied 400 Hz power will be utilized in the SMS wherever necessary. The AC power cabinet will have control of this power by means of circuit breakers and contactors.

The 115V, single-phase, 400 hertz power will be distributed to loads through isolation transformers to help separate grounding systems. The 26V, 400-hertz power will be generated by stepdown transformers and protected by circuit breakers.

#### 4.4.1.4 Power Sequence Control

A power sequence control panel will be located on the AC power cabinet. It will be designed to minimize turn-on surge current by sequencing the loads automatically at timed intervals. Feedback loops from the equipment will be used to initialize the succeeding power loads. If the feedback signal is not received, the turn-on sequence stops, requiring a recycle initiation or correction of the fault.

Manual mode will enable maintenance personnel to trouble shoot the complex. In this mode loads may be turned-on in any sequence.

A system on/off switch will initialize the turn-on sequence. Remote switches at the Pilot/CDR Instructor's stations will enable instructor initialization of the auto sequencing.

A Maintenance in Progress switch will prevent system power turn-on, thereby protecting maintenance personnel from potential shock hazards.

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The sequence control turn-on order will be:

- 1) Hydraulic Power
- 2) Air Compressors
- 3) Cabinet Blowers
- 4) Linkage Ready/Fail
- 5) DC Load (MBCS)
- 6) DC Load (FBCS)
- 7) 400 Hz Load
- 8) Visual Power

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#### 4.4.1.5 Power Cabinet Failures Indications (Figure 4.4-3)

A FAILURES INDICATIONS(FI) panel will be located at the AC power cabinet and will display lights indicating Overheat, Air Flow and Power Supply failures. A test switch will be incorporated to allow lamp test of the indicators.

##### 4.4.1.5.1 Overheat

Dual sensors will be placed in all cabinets and cockpit areas where potential overheating problems exist. One sensor will be set at 100°F and will cause both an aural and visual (FI panel) warning. The second sensor will be set at 110°F and will cause power shutdown in the event that this temperature is reached.

##### 4.4.1.5.2 Air Flow

Air flow sensors will be located in cabinets having fans or blowers. Indicator lights on the FI panel will illuminate whenever air flow is obstructed (e.g., clogged filter).

##### 4.4.1.5.3 Power Supply Status

An indicator light on the FI panel will illuminate whenever a specific DC power supply is not operating.

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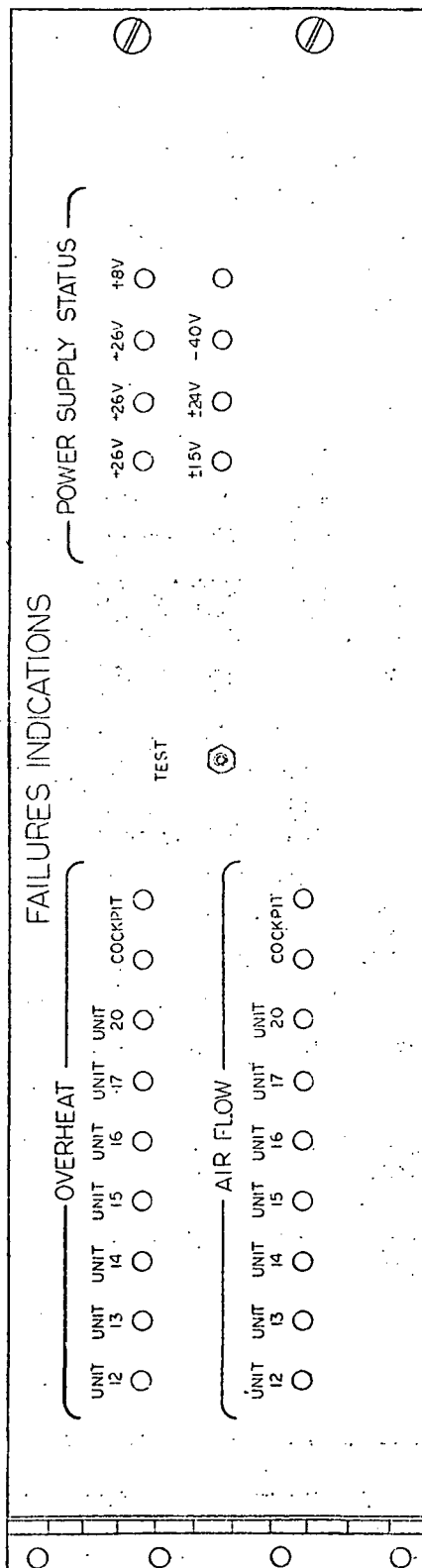


Figure 4.4-3  
FAILURES INDICATIONS PANEL (TYPICAL)

4.4.1.6 Electromagnetic Compatibility

EMI source minimization and containment techniques fall into the following categories:

- 1) Grounding
- 2) Bonding
- 3) Isolation of signals
- 4) Application of suppression devices
- 5) Shielding

The following paragraphs describe the techniques in each category that will be applied to the design of the SMS.

4.4.1.6.1 Grounding

A single-point-reference grounding system will be established to control conducted interference on current return circuits, provide effective shielding, and protect personnel from electric shock. The ground subsystems, such as chassis ground and signal ground, will be completely isolated from one another, except at the central ground point, which will serve as the single-point ground for the system.

A signal ground plane of highly conductive aluminum will be established for DC voltage return distribution (signal ground). Material cross-section area will be evaluated on the basis of the DC current requirements, distance, and skin effects. The central ground plane and connecting radial sections will remain isolated from the copper tubing chassis ground except for a single-point connection at a central ground point.

The design and construction of the equipment will ensure that all external parts, surfaces, and shields are at ground potential at all times. Any external or interconnecting cable, where

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a ground is part of the circuit, will carry a ground wire in the cable terminated at both ends in the same manner as the other conductors. In no case, except with coaxial cables, will the shields be depended upon for a current-carrying ground connection. Plugs and convenience outlets for use with portable tools and equipment will have provisions for automatically grounding the frames or cases of tools and equipment when the plug is mated with the receptacle.

Initial requirements for establishing a grounding system will be as follows:

- 1) To provide a safety ground to personnel.
- 2) To provide a low-impedance return for induced currents on consoles, chassis, cable shields, etc.
- 3) To provide a signal-ground system that will not compromise the shielding effectiveness or safety consideration of chassis ground.
- 4) To provide the capability for the removal or modification of a system component without impairing the overall grounding system.
- 5) To provide a system that will be compatible with future modifications or extensions.

#### 4.4.1.6.1.1 Chassis Ground

Equipment cases, cabinets, racks, and electronic equipment enclosures will be referenced to the chassis grounding system, which will consist of copper tubing (95% International Annealed Copper Standard) with a minimum inside diameter of 0.75 inches. Mating surfaces will be (preferably) welded by exothermic process around the entire periphery of the mating surfaces.

Bolted sections, such as that depicted in Figure 4.4.1-1 will have consistent contact pressure over an extended period of time, possess high resistance to corrosion effects, and exhibit a resistance no greater than 0.5 milliohms. Bonding connections will be made as depicted in Figures 4.4.1-2 and 4.4.1-3 using methods approved by NASA in NHB 5320.3.

The chassis ground will be run under the computer floor, as shown in Figure 4.4.1-3, directly beneath the electronic cabinets to facilitate the bonding of the chassis ground of the cabinet by means of a bond strap of minimal length. All exposed conductive parts, shields, control shafts, switch handles, bushings, etc., will be grounded to the chassis ground for safety considerations to operating personnel. Internal metal parts and modules, filter cases, transformer shields, etc., will also be grounded to chassis ground.

#### 4.4.1.6.1.2 Signal Ground

The signal ground plane will consist of a large aluminum bus bar at least 8 inches in width which will be placed beneath the floor. The bus bar will be close enough to the surface to facilitate bonding to the signal ground busses in the cabinets using bonding straps with good width-to-length ratios.

The width of the bus will be chosen to maintain a signal ground of low impedance to fast-rise-time signals. The signal ground will be isolated from all other ground except at the central ground point.

In the event that the chassis ground and signal grounds are connected together in a piece of commercial equipment, a significant



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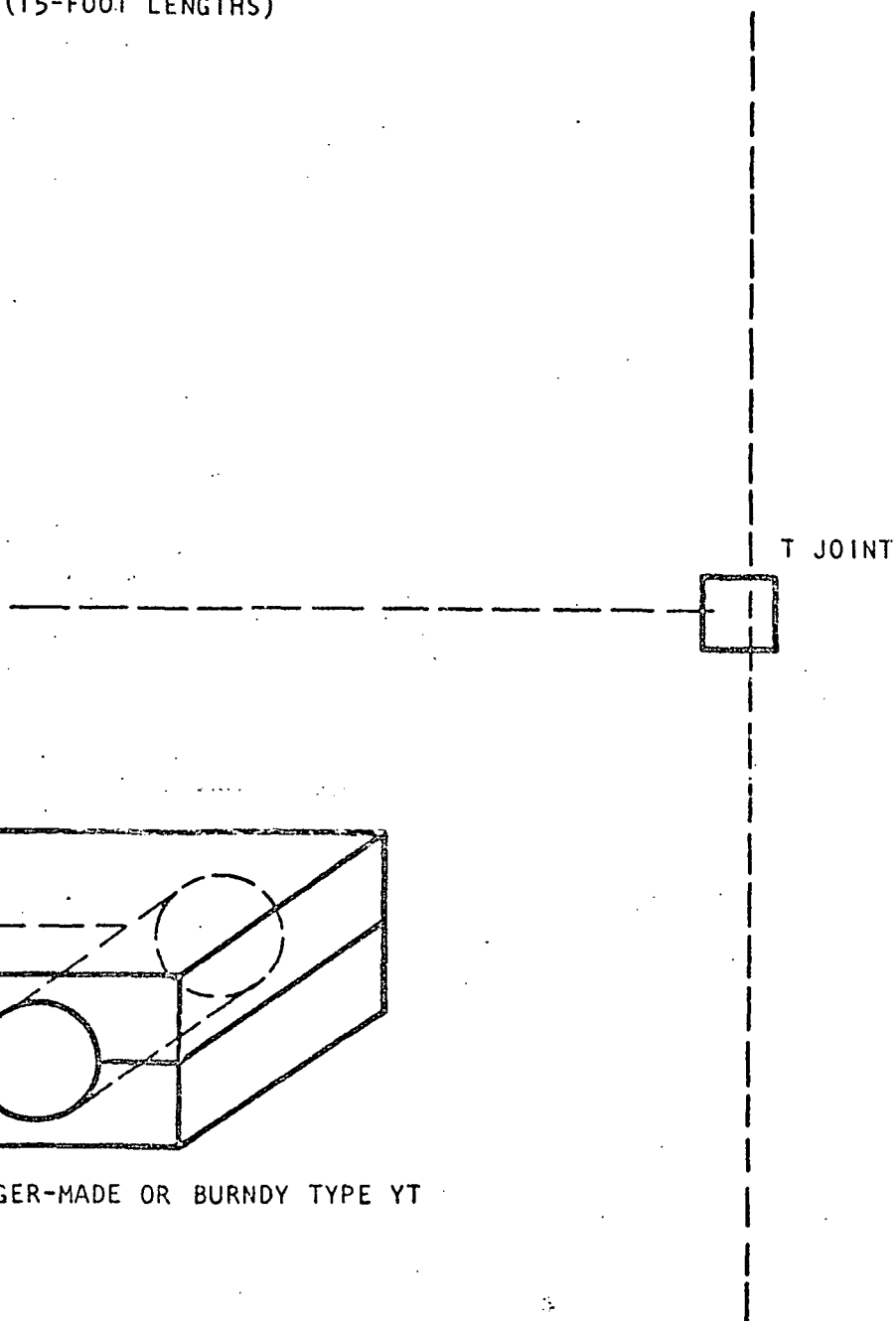
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----- 3/4" ID 95% IACS TUBE  
(15-FOOT LENGTHS)



T JOINT - SINGER-MADE OR BURNDY TYPE YT

Figure 4.4.1-1 CHASSIS GROUND SYSTEM CONSTRUCTION

METHOD OF CONNECTING BOND STRAPS  
TO CHASSIS GROUND BUS  
(FROM AFSC DESIGN HANDBOOK DH 1-4)

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SUB-NOTE 1(1) CLAMP  
CONNECTION - JUMPER  
TO TUBE

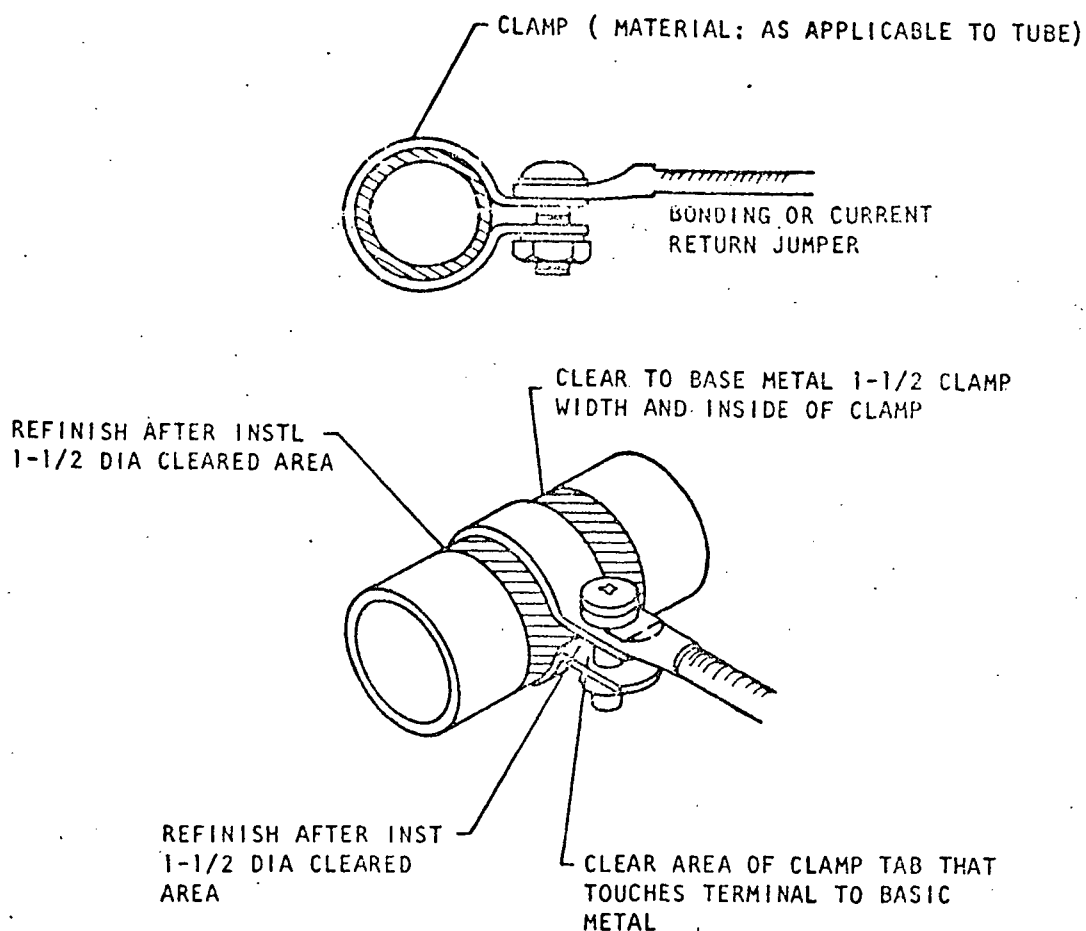


Figure 4.4.1-2

METHOD OF CONNECTING BOND STRAPS TO CHASSIS GROUND BUS

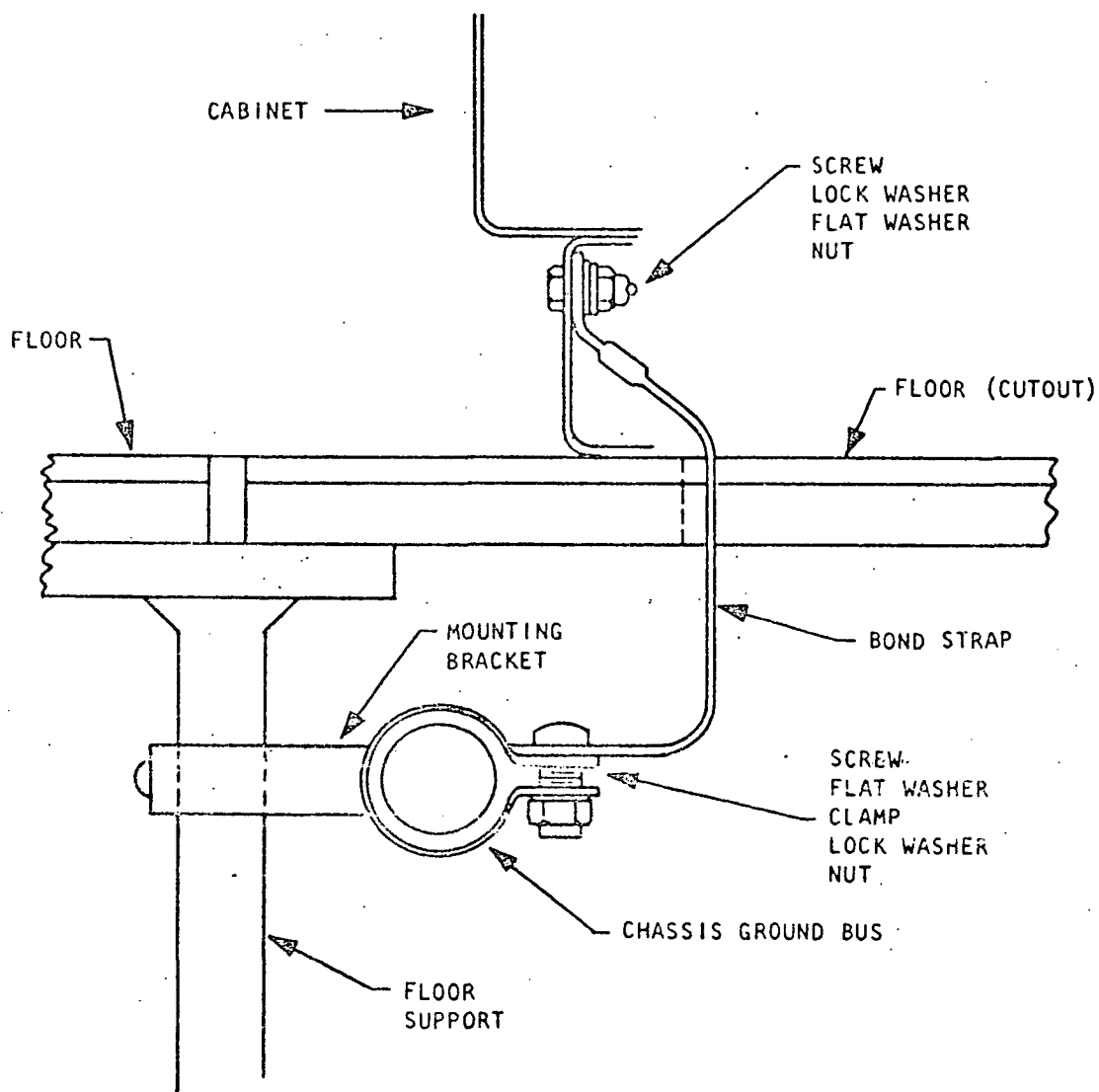


Figure 4.4.1-3

METHOD OF CONNECTION OF CABINET TO CHASSIS GROUND

effort will be applied to isolate this unit from the rest of the equipment and reference it to the low-impedance signal ground bus.

#### 4.4.1.6.1.3 Primary Power Neutral

Primary power sources and circuits will not be directly grounded to chassis or signal ground within the simulator. Each AC neutral will be routed with its associated power leads and maintained above earth potential in all equipment stations.

The AC voltage feeding all internally grounded instruments or panel loads will be supplied from isolation transformers whose secondary leads will be run to each load. The secondary of the isolation transformer will be grounded at the load end only in a manner not dependent on the mounting of the instrument case to the panel. This grounding will be achieved by a separate wire bonded directly to the panel with a screw and nut. The instrument will not be dependent on its mounting to provide a reference ground.

#### 4.4.1.6.1.4 Interface Grounds

Interfaces between the flight simulator equipment will be provided with chassis ground interconnections as follows:

- 1) Each cable carrying primary or secondary AC or DC power will be provided with a chassis ground wire.
- 2) Power and signal returns will not be used as chassis ground wires.
- 3) A minimum of one interconnecting chassis ground will be required for each interface. If there is no power cable interconnection, the ground will be routed in the cable carrying the most

sensitive circuits. Interfaces for commercial metering or signal-generating circuits will be exempt from this interface chassis ground requirement.

- 4) Interfaces of coaxial cables will not require additional ground interconnections. Coaxial cables will not be used for the interconnecting grounds for other cables.

#### 4.4.1.6.2 Electrical Bonding

The electrical bonding procedures of MIL-STD-1310 and MIL-B-5087 will be utilized as design guides. Bonding considerations fall generally into the following categories:

- 1) Bonding of the enclosure to an equipment ground reference.
- 2) Bonding of separable or movable parts or openings.
- 3) Bonding of ground cables to the associated ground.
- 4) Bonding of the major subassembly to chassis ground.

The bonds between the equipment and the central ground point will be designed to carry the maximum short-circuit fault current load of the equipment.

All electrical and electronic units or components which produce electromagnetic energy will be installed to provide a continuous low-impedance path from the equipment enclosure to the central ground point. Bonding will be designed to provide for a direct current impedance of less than 2.5 milliohms from the enclosure to the central ground point. The bond from the equipment enclosure to the mounting plate furnished with the equipment will also comply with these requirements, except that suitable jumpers may be used across any necessary vibration isolations. The ratio of length to

width of the jumper braid cables will be 5/1 or less.

Protective finishes will be omitted at those points where their presence would prevent proper electrical bonding, such as required for shielded or electrical connection. Provision will be made to assure permanence of the electrical contact between the surfaces of all parts in contact over long periods of time.

Bonding installations will be considered as being permanent and inherently bonded when utilizing metal-to-metal joints by welding, brazing, sweating, or swagging. Insulating finishes will not be removed if the resistance requirement is met without such removal. Examples of semipermanent installations are:

- 1) Bare metal-to-metal joints of machine surfaces held together by thread-locking devices.
- 2) Riveted joints with a minimum of three rivets.
- 3) Tie rods.
- 4) Structural wires under tension.
- 5) Pinned fittings driven tight.
- 6) Normally permanent and immovable clamp fittings which have been removed from the contact area.

Bonding connections will be so installed that vibration, expansion, contraction, or relative movement incident to normal service use will not break or loosen the connection to such an extent that the resistance will vary during the movement. Bonding connections will be located in protected areas, insofar as practicable, and whenever possible near a hand hold, inspection door, or other accessible locations to permit rapid inspection or replacement. The following conditions will also apply:

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- 1) Parts will be bonded directly to the basic structure rather than through bonded parts. Shielded wire grounds will be carried through the pins of a connector or attached directly to the grounding structure. Bonding through the connector shells will be permitted, provided the resistance through the shell is not greater than 2.5 milliohms.
- 2) Bonding jumpers will be installed so that movable components are not impeded in their operation by the jumper.
- 3) Bonding connections will not be compression-fastened through nonmetallic materials.
- 4) Bonds on plumbing lines will not be dependent on mounting clamps because of differential thermal expansion.
- 5) Cushion clamps will not be used for bonding purposes.
- 6) All equipment cabinets will be furnished with mounting holes for studs for a bonding strap ground connector.
- 7) The use of conductive epoxy resins will be permitted, provided they conform to the performance requirements of the SMS contract. When bonding by jumpers would cause fouling or mechanical malfunction, other suitable means will be employed.
- 8) Bonding of cylindrical or tubular conducting members not inherently bonded will be accompanied by a clamp with a jumper. Bonding clamps, when required on flexible metallic conduit or hose, will be so installed as not to crimp or damage the conduit or hose.

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- 9) When joining dissimilar metals cannot be avoided, the jumpers and other elements of the bonding connection will be selected to minimize the possibility of corrosion. If corrosion does occur, only replaceable hardware items, such as jumpers, bolts, nuts, washers, or separators, will be affected rather than the structure. Self-tapping screws and zinc-plated bolts, nuts, and screws will not be used. Washers will not be surface-treated or coated in any manner that will impair electrical conductivity. Unprotected, non stainless steel will not be used as a washer. Anodized or zinc-plated washers will not be used.

Intermittent electrical contact between conducting surfaces which may become a part of a ground plane or a current path will be prevented wither by bonding or by insulation if bonding is not necessary to conform to this standard.

4.4.1.6.3 Methods of Eliminating Spurious Responses and Connections

4.4.1.6.3.1 Isolation of Signals

Wires and cables will be classified as delineated below:

Class I - Class I wires are interference-producing wires which interconnect equipment, or circuits that are insensitive to interference. Examples of Class I are alternating current (AC) power wiring, relay and stepping motor wiring, actuating power wiring, and flashing incandescent and fluorescent wiring.



Class II - Class II wires are those that in themselves are not interference-producing, but are connected to interference-sensitive equipment or circuits. Examples of Class II are audio and video outputs, metering and bridge circuits, direct current (DC) and AC reference voltages, and receiver inputs.

Class III - Class III wiring includes those circuits and equipment interconnections that are both interference-producing and sensitive to interference. Examples of Class III are pulse inputs and outputs of digital equipment.

Class I wires that are cabled together will be separated from Class II and Class III cables by a minimum of 6 inches or will be run at right angles to them. Class II wires cabled together will be separated from Class III wires by a minimum of 3 inches. Routing of cables will be determined mainly by the interference producing or susceptibility characteristic of each. Cables and wiring inside cabinets will follow the minimum separation distances given above wherever possible.

#### 4.4.1.6.3.2 Application of Suppression Devices

All relays and other inductive devices, such as solenoid valves, will be protected by diode, capacitor, or resistor suppressive devices.

Diode/capacitor decoupling will be used on each printed circuit card, as well as being distributed throughout the logic gates. Particular attention will be paid to the impedance and resonance frequency characteristics of bypass components to ensure proper bypassing for required frequency components.

All high-frequency circuits will be decoupled as close as possible to the generating circuits.

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#### 4.4.1.6.4 Shielding

Shields of low-level signal leads and of leads associated with steep-wavefront signals will be grounded at one point only and will be routed through pins of all connectors encountered. Digital input-output cabling will consist of wires surrounded by an overall shield which is terminated via a shielded twisted pair or twisted triplet cable. Other shielding configurations may be utilized, depending on the frequency involved, length of transmission, and amplitude of the signal level. Shields of all leads external to the equipment will be covered with an insulating material to prevent unintentional contact with conductive surfaces, except in the case of rigid conduit.

Each shield of low-level circuits will be grounded at one point only, preferably at the source end. The length of wire tying the shield to ground will be as short as possible, and never longer than 6 inches (see Figures 4.4.1-4, 4.4.1-5 and 4.4.1-6). Each shield of high-energy circuits used to contain low-frequency energy (less than 1 megahertz) will be grounded at one point only to chassis ground. The wire used to tie the shield to chassis ground will be as short as possible.

Each shield of high-energy circuits used to contain high-frequency energy (greater than 1 megahertz) will be grounded at each end as shown in Figure 4.4.1-6.

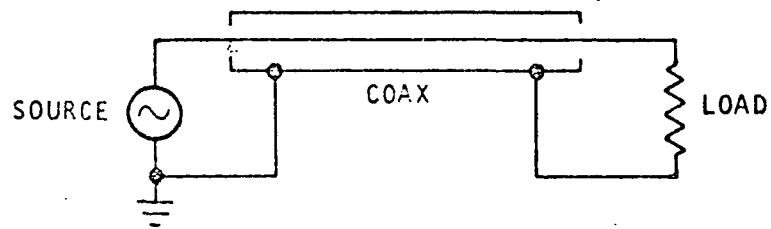


Figure 4.4.1-4 SHIELD GROUNDING OF LOW-FREQUENCY CABLES

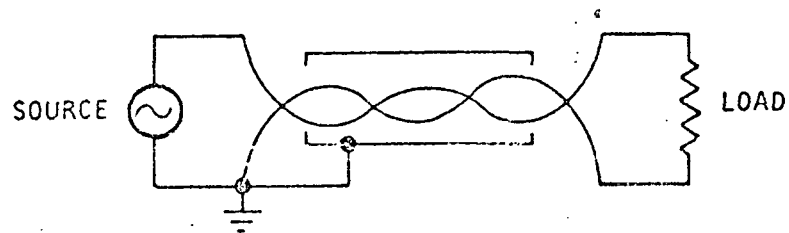


Figure 4.4.1-5 SHIELD GROUNDING OF TWISTED-WIRE CABLE

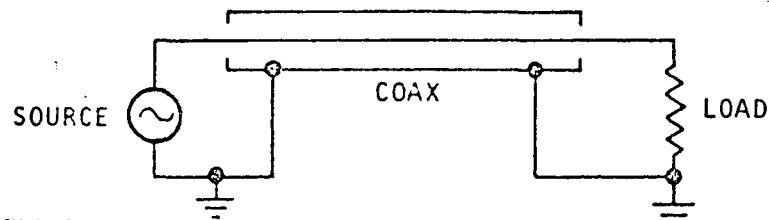


Figure 4.4.1-6 SHIELD GROUNDING OF HIGH-FREQUENCY COAXIAL CABLE

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Coax will be grounded as shown in Figure 4.4.1-4, except when it is carrying high energy (greater than 5 watts) at high frequency (greater than 1 megahertz), in which event it will be grounded as shown in Figure 4.4.1-6.

All shields of audio circuits will be grounded at one end only. Wherever possible, audio shields will be grounded as shown in Figure 4.4.1-5. The actual ground point will be at the source end. All audio leads greater than 6 inches in length will be twisted and shielded. The wires tying shields to ground will be as short as possible, and no longer than 6 inches. Audio shields will be referenced to the chassis ground.

Low-level video shields will be grounded as shown in Figure 4.4.1-5. Different shields may be referenced to different video ground planes as required, but each shield will be referenced to ground at one point only.

#### 4.4.2 Aural Cue System

##### 4.4.2.1 General Requirements

Aural cue simulation is becoming increasingly important in the light of the added complexities of modern aircraft. Human-factors studies have shown that aural cues have a significant effect on the training performance of students attempting to become proficient in highly complex skills. This effect manifests itself in two ways:

1) The training environment is greatly enhanced because auditory stimuli are second in importance only to visual stimuli in the flight environment; kinesthetic stimuli rank third.

2) Learning curves and concentration abilities are subject to degradation within the confines of high ambient noise environments. Within the cockpit of a modern aircraft it is not uncommon for the ambient noise level to reach sustained values of 90 to 110 db. Within this environment, even the advanced student's learning curve could be degraded some 15%. There is some evidence to support the contention that reaction times are elongated, the latency of response being a function of the nature of the decision that is required to result in the corrective action.

Aural cue simulation requirements for the MBCS include the generation of a large repertoire of sounds as needed to represent the Shuttle Orbiter Vehicle acoustic environment during normal and abnormal operation.

The system conceived for the MBCS will consist of five simultaneously occurring subsets of aural events, whose combination forms a single, highly complex presentation. Within each subset there are specific, discernible events characteristic of particular mechanisms whose sounds emerge from their different directions.

These aural events simulations will be implemented by a combination of mathematical models and associated computer programs and electronic equipment as described below.

#### 4.4.2.2 Aural Effects Models

1) ABPS Engines (4) - This model will include LP compressor, HP compressor, HP turbine, LP turbine, and jet blast sounds for each Pratt and Whitney F401-PW-400 engine, inclusive of engine deployment, starter sounds, ignition, reverse thrust conditions, primary compressor stalls, and in-flight flameouts, all with altitude and airspeed corrections.

2) Rocket Engines (SRM, MPS, RCS)

a) SRM (2) - This model will include thrust sound and vibration, start-up, shutdown, and thrust termination noises.

b) MPS (3) - This model will include rocket engine blast with throttle controllable sounds, start and post firing metal expansion/contraction noises, and system purging.

c) RCS (3) - This model will include jet "thump" and blast.

3) Aerodynamics

This model will include aerodynamic air flow to structural noise as a function of aircraft attitude, altitude, and airspeed corrections. Transonic and supersonic performance effects will be provided. Popping and cracking sounds associated with reentry will also be provided.

4) Auxiliary

This model will include taxi pavement noise, landing gear, wheel touchdowns, air-conditioning duct blasts, hydraulic motor hum, pyrotechnic noises, electrical system, and full cell venting sounds.

5) Clunk Noise Generator -

This model will include the various "clunks", "bangs" and "thumps" of the spacecraft such as; drag chute and speedbrake deployment, manipulator arm mating and stowage, cargo latching and unlatching, pyrotechnic separation, and docking.

All aural cues will be presented within the cockpit enclosure as quasi-elevated (nonplanar), bilateral, quadriphonics with "sounds in motion" where required as a realistic adjunct to the training environment.

4.4.2.3 Aural Cue Electronic Equipment

Electronic equipment for the aural cue simulation will consist of a device called the Poly-Voice Aircraft Sound Synthesizer\*\* plus audio amplifiers and sound transducers placed at selected locations in the crew station. (Figure 4.4.2-3)

\*\* Patent applied for.

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The Poly-Voice Synthesizer itself will consist of an array of electronic function generators (VCG's) and controllers (VCA's) designed according to the required configuration of parametric elements, as shown in Figure 4.4.2-1. The following paragraphs describe the system in detail, with reference to Figure 4.4.2-1.

#### 4.4.2.3.1 Engine Sounds

Sounds of the ABPS turbofan jet engines will be implemented by means of system parameters A1 through A10. Primary acoustic constraints will be systematically related to the main moving parts of the F401 engine. A1 will generate the HP turbine blade passage frequency of proper timbre (harmonic content) under the control of the N1-related computer function "ElFA". A2 will suitably control the amplitude of this blade passage whine via controlling function "ElAA". Similar functions ("ElFB", "ElAB" and "ElFC") will control parameters A3, A4, A5, and A6 to simulate the low- and high-pressure compressor blade frequencies. Jet blast will be effectively simulated by means of a clocked pseudo-random noise generator that provides a unique method of accurately controlling the spectral makeup of the noise relative to engine performance parameters. Module A9 will control the jet blast amplitude relative to the blade passage frequencies, while A10 will sum the components and provide a composite acoustic facsimile which may later be modified during "transonic/supersonic" performance.



AURAL CUE CABINET

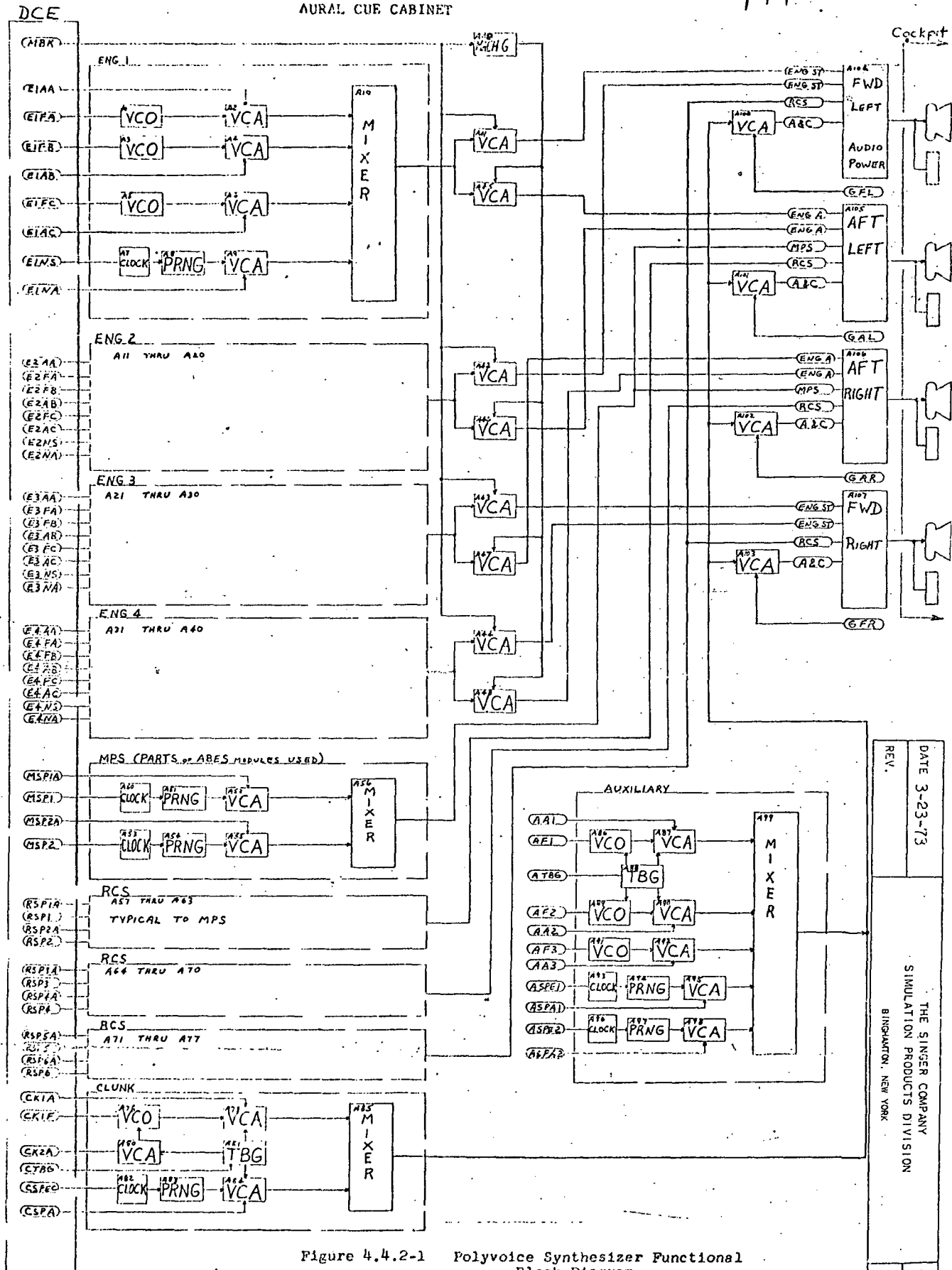


Figure 4.4.2-1 Polyvoice Synthesizer Functional Block Diagram

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Engines 2, 3, 4 will be independently simulated in a similar fashion with parameters All through A40. The additional engine signals will also be subjected to modification during transonic/supersonic flight, and the mutual acoustic constraints of the multi-engined configuration will be accounted for.

#### 4.4.2.3.2 Mach Shift

Rocket engine acoustics during transonic and supersonic flight necessitate special concern because the engine noise is the only primary acoustic frame of reference. This noise will therefore be subject to the transmission degradation that occurs whenever the speed of the acoustic source (or fluid transmission mechanism) relative to the observer exceeds the propagation rate of sound. Since the engine noise will be presented to the observer (trainee) via two separate paths - an airborne link and a structural link - "stereophonic source localization" will occur. At subsonic speeds, when both transmission links remain unaltered, the engines will appear to be just forward of their real position, dependent on the delicate amplitude balance of the multipath presentations. During transonic and supersonic flight, the airborne transmission path will be either partially or totally reduced. The result of such a multipath balance disturbance will be an apparent shift forward in localization just as occurs in the actual spacecraft.

Since the aircraft structure more easily transmits the lower-frequency noise, the acoustic makeup of the engine noise will be

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changed. Hardware parameters A41 thru A44 will provide engine signals representative of structural transmission, while A45 thru A48 will provide a close facsimile of airborne contributions. The function "MBK" and controller A48 will provide suitable control over the supersonic modifiers. Proper directional cues will result from the quadriphonic audio power system. (see Figure 4.4.2-3 for speaker locations)

#### 4.4.2.3.3 Aerodynamic Noise

Slipstream air and structural noise will be provided by a separate source A97 that is capable of well-defined control of its spectral content as a result of controllers A96 and A98 which reflect acoustic parameters dependent on aircraft (Mach) and logarithmic altitude.

#### 4.4.2.3.4 Auxiliary Sounds

A number of auxiliary sounds will be provided in multiplexed fashion by hardware elements A86 to A99 owing to their time sequenced rather than simultaneous nature. The individual cues, such as air conditioning, taxi, pavement or touchdown, and associated gear motions, will be created by commanding the proper acoustic parameters with the functions AF1, ATBG, etc., and defining a particular direction of initialization with direction-select gates, A100 through A103.

#### 4.4.2.3.5 Clunk Noise

The various "bangs", "thumps", and "clunk" noises associated with spoiler deployment, docking, pyrotechnic separation drag chute, and manipulator arm mating, will be created by hardware elements

A78 through A85. Directionality will be controlled by direction-select gates A100 through A103.

#### 4.4.2.3.6 System Packaging

The Poly-Voice sound system is packaged in three 19-inch rack-mounted modules (see Figure 4.4.2-2). The upper module is a rack mount tray 7 inches high which mechanically supports and electrically isolates a four-channel power amplifier. The power amplifier receives its input signals from the lower module and delivers output power to sound transducers mounted at four locations in the cockpit of the flight simulator.

The center module is a housing for the three DC power supplies occupying another 7 inches of rack height. This module also contains three pilot lights, five phone jacks, three fuses, and power switch. The pilot lights are connected individually to the outputs of the three power supplies. The phone jacks are connected to each of the four output channels and one composite channel formed by summing the other four. A separate fuse for each side of the line and a spare fuse are mounted on this panel.

The lower module is a card cage 10½ inches high containing functional (four types) 4½ x 12-inch circuit cards and an extender card for use in calibration or repair. The functional circuit cards hold the circuitry which generates, mixes, and controls the waveforms which comprise the composite output signals. Built-in test modes facilitate troubleshooting and maintenance of the system.

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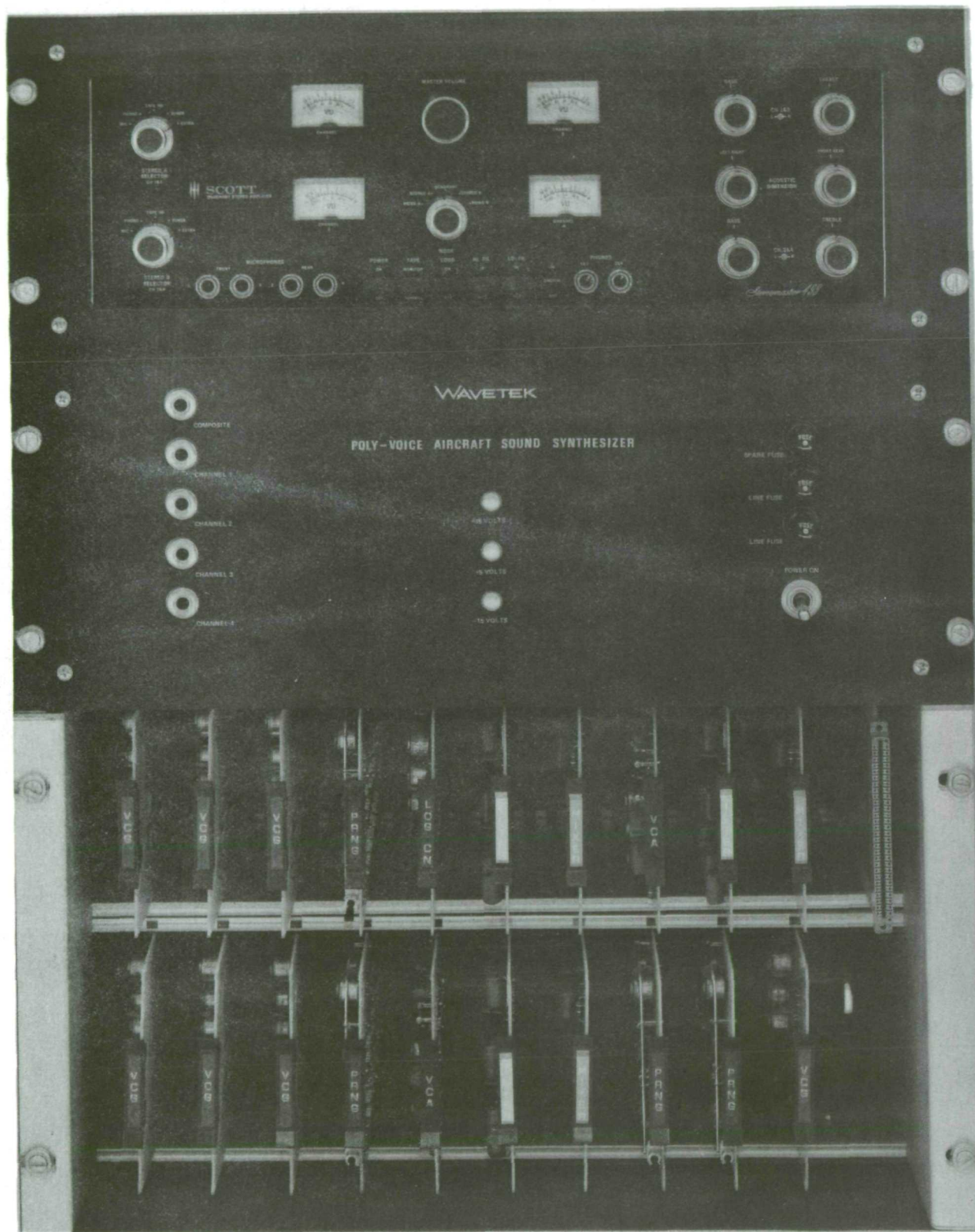


Figure 4.4.2-2 POLYVOICE SOUND SYNTHESIZER PACKAGING

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LEGEND



= SPEAKER



= AUDIO TRANSDUCER

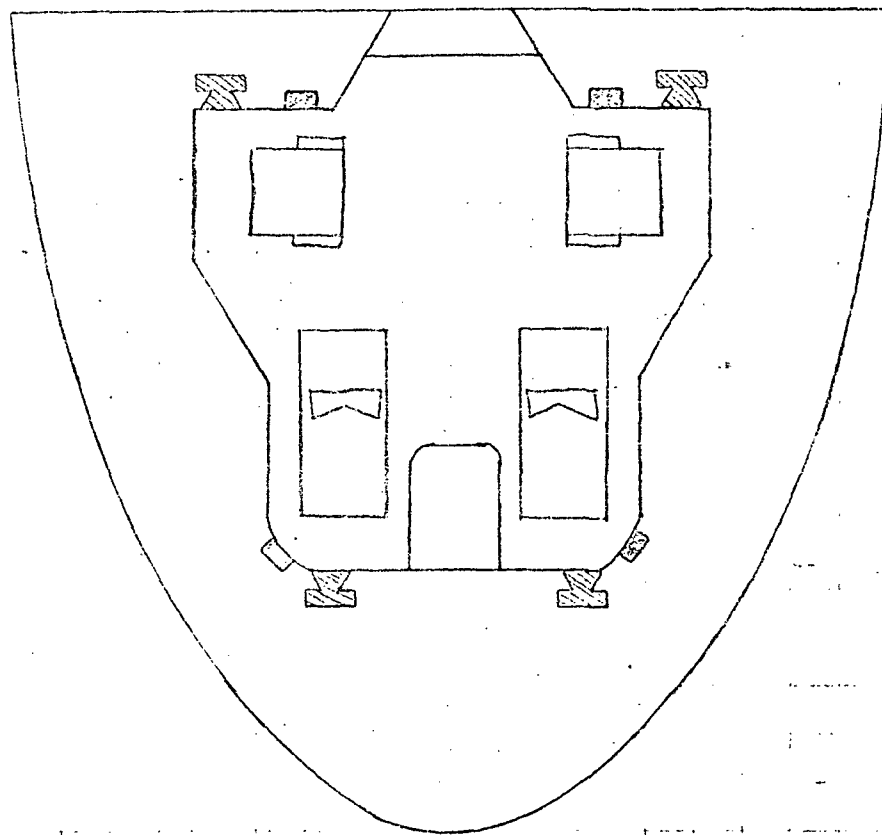


Figure 4.4.2-3 Aural Cue Speaker Locations

#### 4.4.3 External Interface

SMS External Interface between Building 5 and Building 30 include Trajectory Data Computer to Computer interface, The Downlink, Telemetry interface, The Command (Uplink) interface, the Central Timing System interface and the Voice Communications interface. With the exception of Voice Communications, a brief description of these interfaces is included in the following paragraphs. The Voice Communications System is discussed in Section 4.4.5.

##### 4.4.3.1 Trajectory Data Interface

This interface presently consists of telephone lines and type 301-B Modems transmitting bidirectional data at 2 14.2 kilobit per second per line rate. It is recommended that these modems be replaced by type 303-C modems or others to give bit rates of the order of 50 kilobits per second per line.

##### 4.4.3.2 Telemetry Data Interface

The Building 5 to Building 30 simulated telemetry interface presently consists of five coax lines. One FM/VCO utilized for channels of Skylab analog biomedical data plus four lines transmitting clock pulses and telemetry data from Building 5 to Building 30 at various rates including 7.2 kilobits per second and 36 kilobits per second. Line drivers will be provided in the SMS to interface with these lines. However, it should be noted that the Shuttle Vehicle is presently understood to include air to ground telemetry data rates of

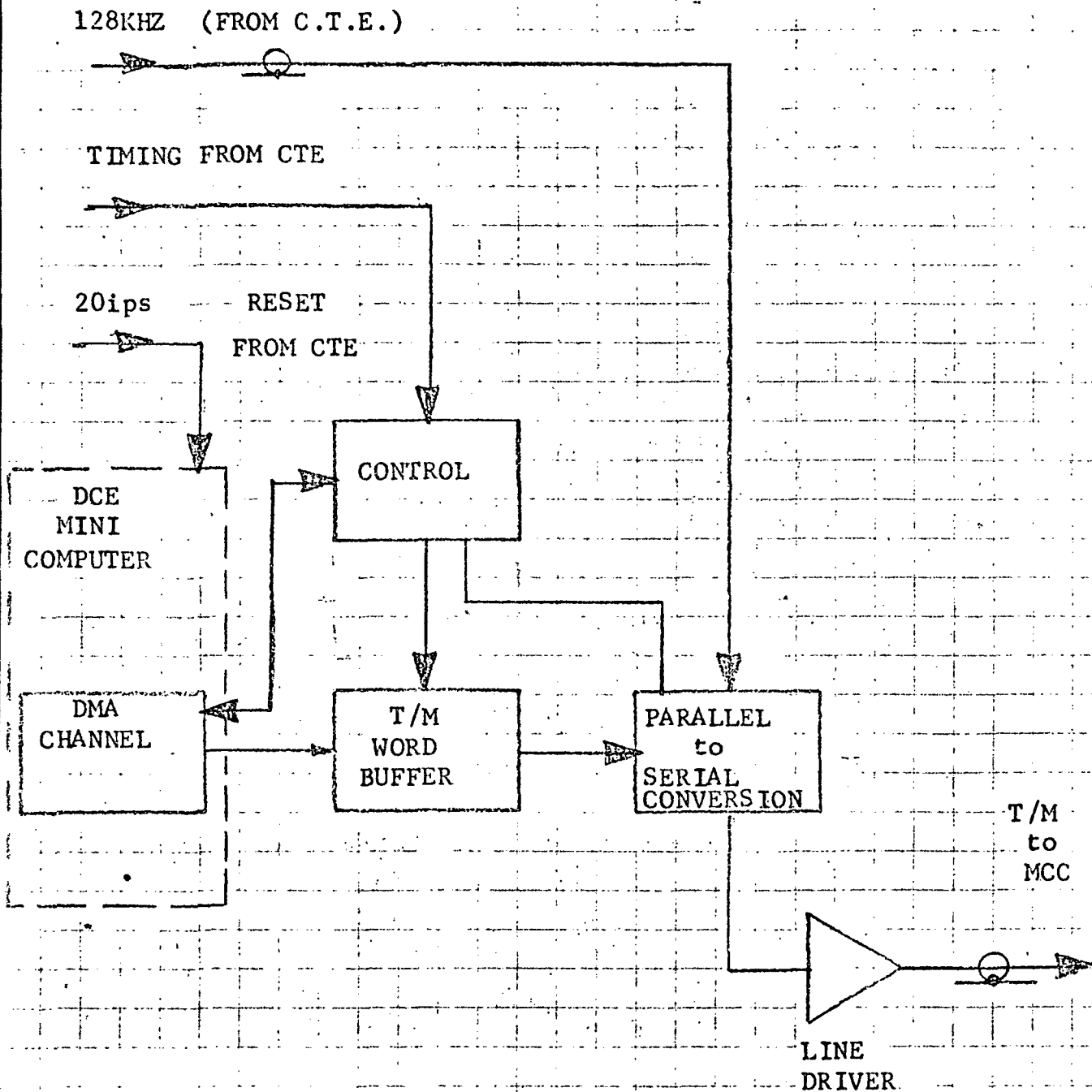


FIGURE 4.4.3-1  
TELEMETRY DATA INTERFACE EQUIPMENT



128 kilobits per second and 256 kilobits per second. A complete review of this interface is therefore recommended, with the intent of establishing simulation requirements for both the air to ground and ground to ground sections of the telemetry link. (Refer to Fig. 4.4.3-1)

#### 4.4.3.3 Command (Uplink) Data Interface

The Command interface consists of four telephone lines from Building 30 to Building 5 transmitting data one way at 1.2 kilobits per second utilizing a type 201-A modem. Two lines are uplink data and two are clock data. The SMS will interface with these lines in Building 5 to accept the uplink command data. (Refer to Fig. 4.4.3-2)

#### 4.4.3.4 Central Timing Interface

To enable the Shuttle Mission Simulator to operate in real time synchronism with the Mission Control Center, timing signals will be provided by MCC to enable this synchronization, and consists of the following:

<u>Frequency</u>	<u>Duty Cycle(%)</u>	<u>Z<sub>out</sub></u>	<u>Logic Levels<sup>1</sup></u>
1 ppm <sup>2</sup>	66 2/3	75-90	0 ± 0.5; -6 ± 0.5
1 pps	80	75-90	0 ± 0.5; -6 ± 0.5
10 pps	80	75-90	0 ± 0.5; -6 ± 0.5
100 pps	80	75-90	0 ± 0.5; -6 ± 0.5
1000 pps	50	75-90	0 ± 0.5; -6 ± 0.5
1 Mhz <sup>3</sup>	50	75-90	0 ± 0.5; -6 ± 0.5

The SMS will utilize these signals to assure time synchronization. Additional details related to the Central Timing Equipment are to be found in Section 4.4.4.

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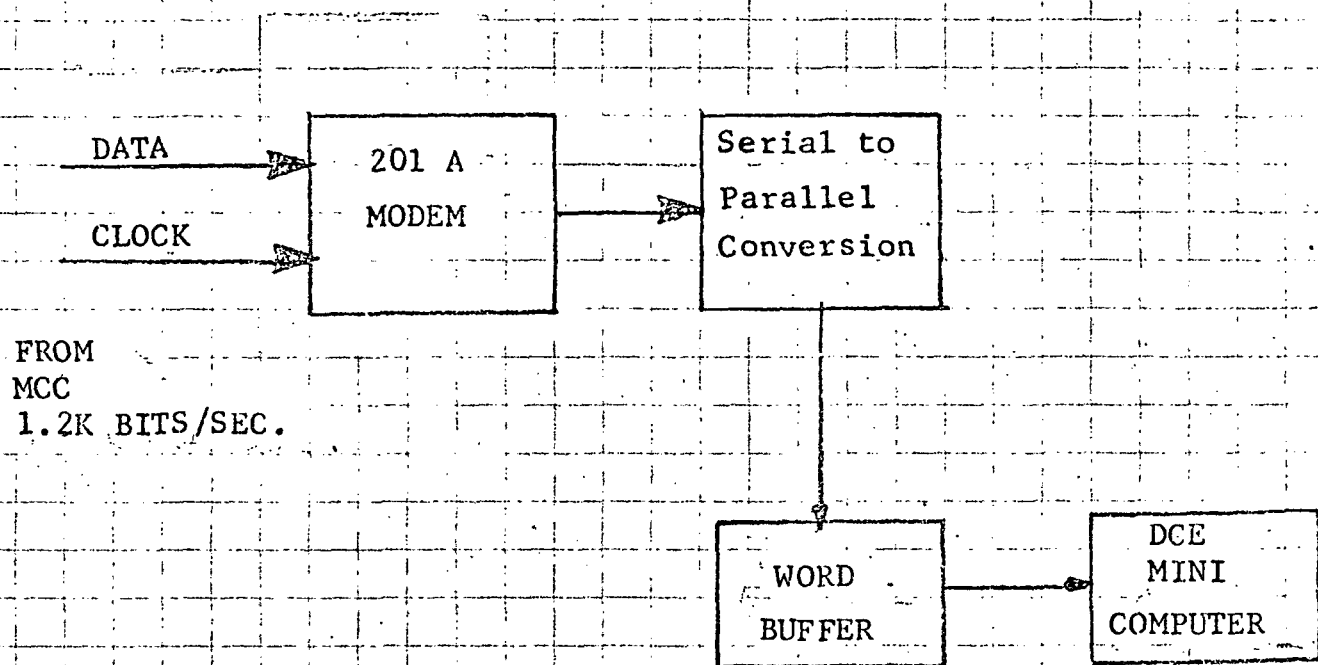


FIGURE 4.4.3-2

COMMAND DATA INTERFACE  
(UPLINK)

#### 4.4.4 Central Timing Equipment (CTE)

Central Timing Equipment will be provided in the SMS consisting of an oscillator and countdown frequency division circuits to provide timing signals of 128 KHZ, 4 KHZ, 50 pps, 20 pps, 10 pps, 1 pps, and 1 ppm. A basic clock frequency of 1 MHZ will be used. In MCC Integrated modes, the CTE will be synchronized with the 1 MHZ timing signals available in Building 5 and identified in section 4.4.3 above.

Line drivers, with coaxial lines, properly terminated, will be provided, to provide suitable pulse signal levels and power levels for the synchronized equipment. A block diagram of one possible approach to the CTE System is shown in Figure 4.4.4-1.

The final design will depend on actual signal frequencies available from MCC and the requirements of the SMS.

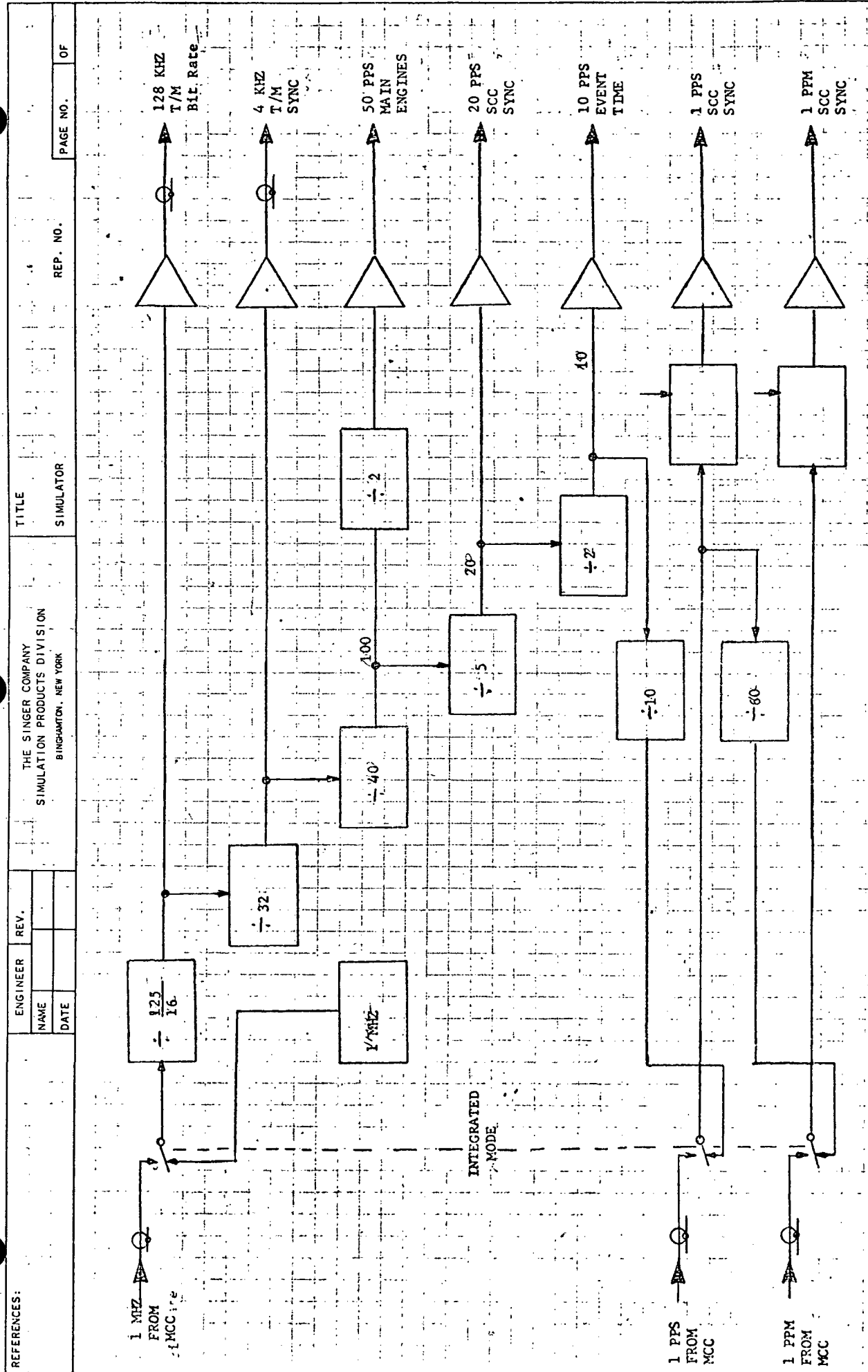


FIGURE 4.4.4-1 CENTRAL TRAINING EQUIPMENT

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#### 4.4.5 Audio Communications System

##### 4.4.5.1 General

The audio communications system for the moveable base SMS consists of four audio control panels; one at each crew station position. The audio panels will control the transmission and reception of simulated S-Band, VHF-1, VHF-2, and Intercom signals. The controls for EXTERNAL communications will not be simulated. The relative volume of each incoming signal will be independently variable. A single Master Volume control can adjust overall volume.

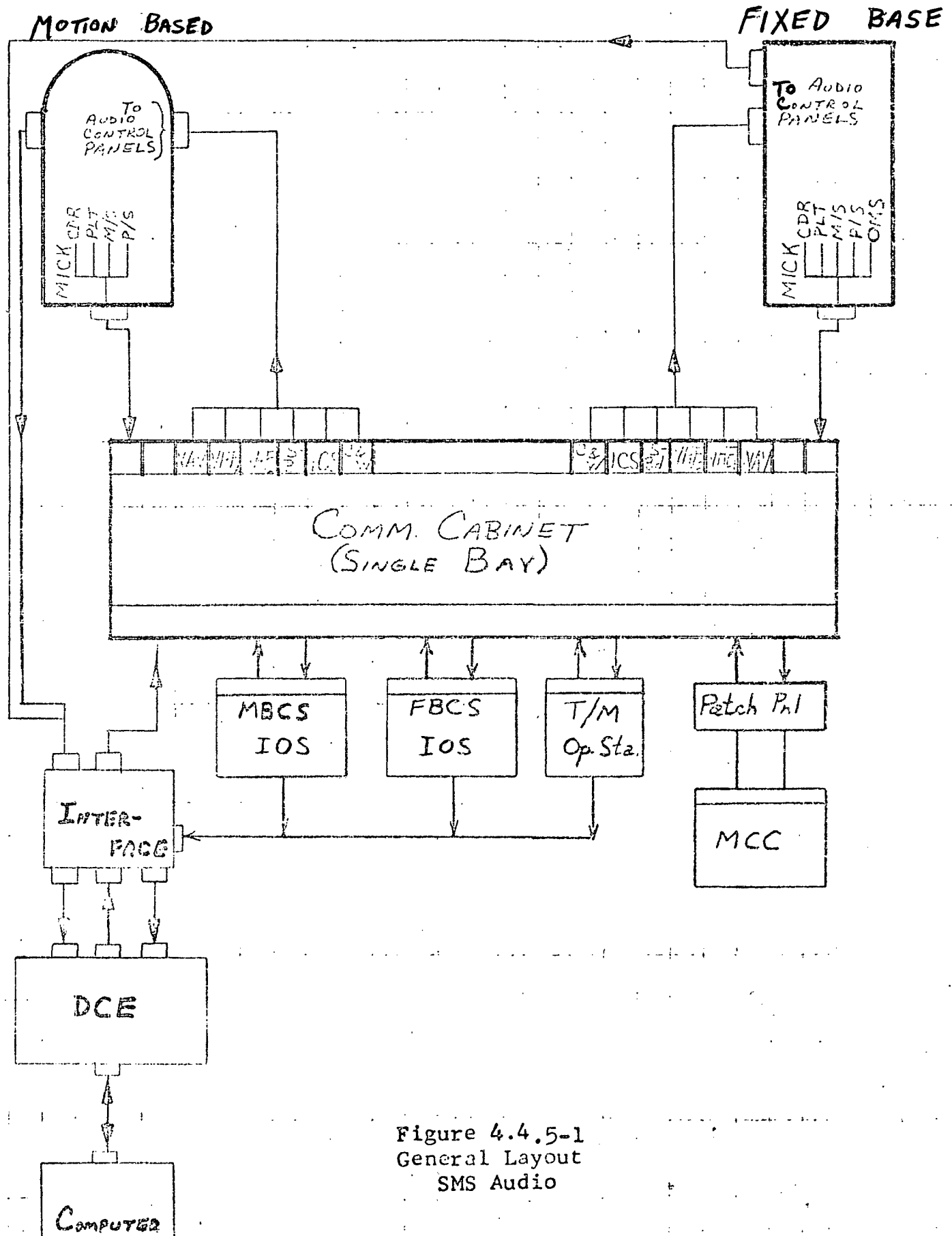
The design approach will be to provide at each panel position a microphone pre-amp/driver, a test oscillator, and a headphone buffer/receiver amplifier. Signal conditioning, routing, isolating or mixing, and driving will be centralized in the Communications System Cabinet. Components will be primarily of the DIP variety.

A general layout Block Diagram is shown in Figure 4.4.5-1

##### 4.4.5.2 S-Band and VHF Communications

Audio communications on the S-band and VHF frequencies will be simulated by means of white-noise generators (WNG) and voltage-controlled attenuators (VCA). (Figure 4.4.5-2)

The instructor's transmissions to the crew will be mixed with white noise. The attenuation of noise and signal will be computer controlled via the DCE which will simulate both range and noise level fluctuations.



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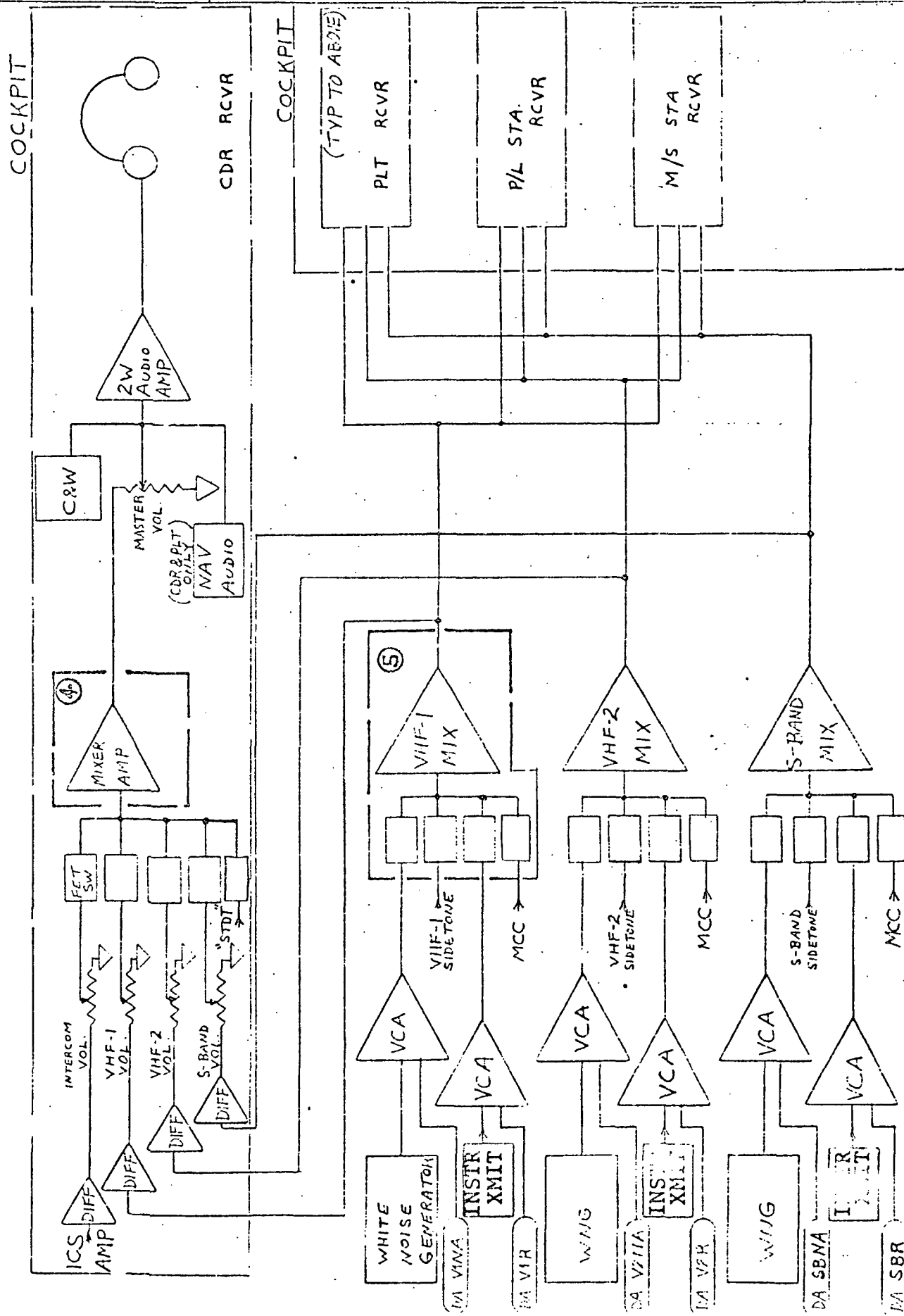


Figure 4.4.5-2

Communications System Audio - Reception

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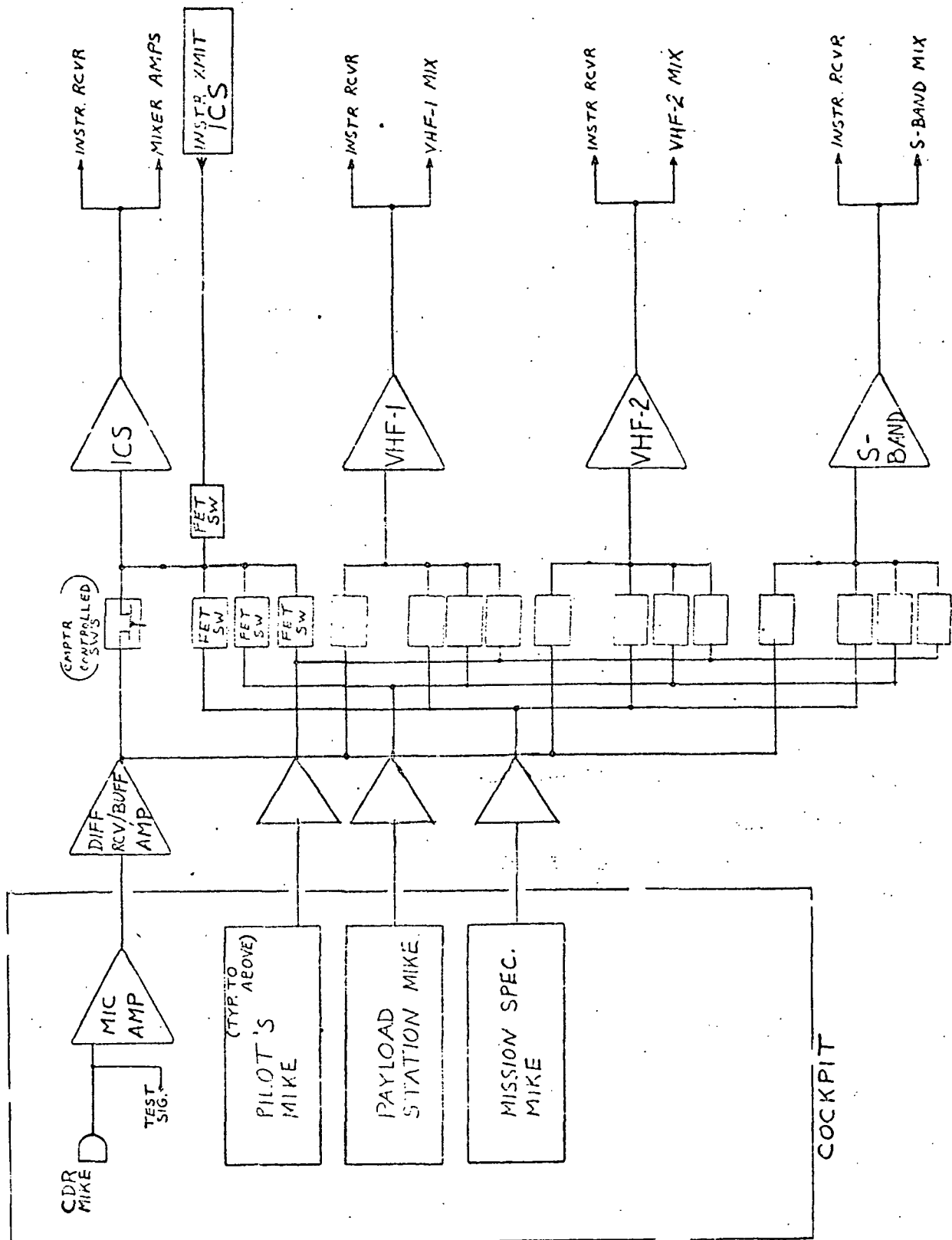


Figure 4.4.5-3  
Communications System Audio - Transmission



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#### 4.4.5.3 NAV Audio

##### 4.4.5.3.1 TACAN

The TACAN tone will be generated by a fixed frequency oscillator (FFO). A computer controlled FET will switch the 1350 HZ tone to generate the desired code. (Figure 4.4.5-4).

##### 4.4.5.3.2 ILS

The ILS tone will be developed in the same manner as the TACAN tone except that a 1020 HZ tone will be used. (Figure 4.4.5-4)

#### 4.4.5.4 Interphone Communications System (ICS)

The ICS will enable all crew members to talk with one another, as well as serving as a communications link to the instructors. (Figure 4.4.5-3). All cockpit controls for the ICS will be operative to the extent of switching and volume control functions.

#### 4.4.5.5 Simulator Maintenance Interphone

The maintenance intercom system for the SMS will be a "party line" or single-loop type, enabling communication and monitoring without station selection. It will consist of a common power supply, a network of interconnecting cables terminated in jacks and plug-in audio equipment. Strategically placed jacks will accept portable speaker and microphone/headset inputs. The audio amplifiers will be self-contained in the units.

Power for the intercom system will be obtained from the utility power distribution network, thus permitting use of the system



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with the simulator power off. Interconnecting cabling will be of the twisted-shielded type, with single-point grounding at the power supply. Crosstalk and noise will be prevented through design and installation techniques, including the prevention of feedback noises at each station.

#### 4.4.5.6 Audio Communications System Detailed Design Features

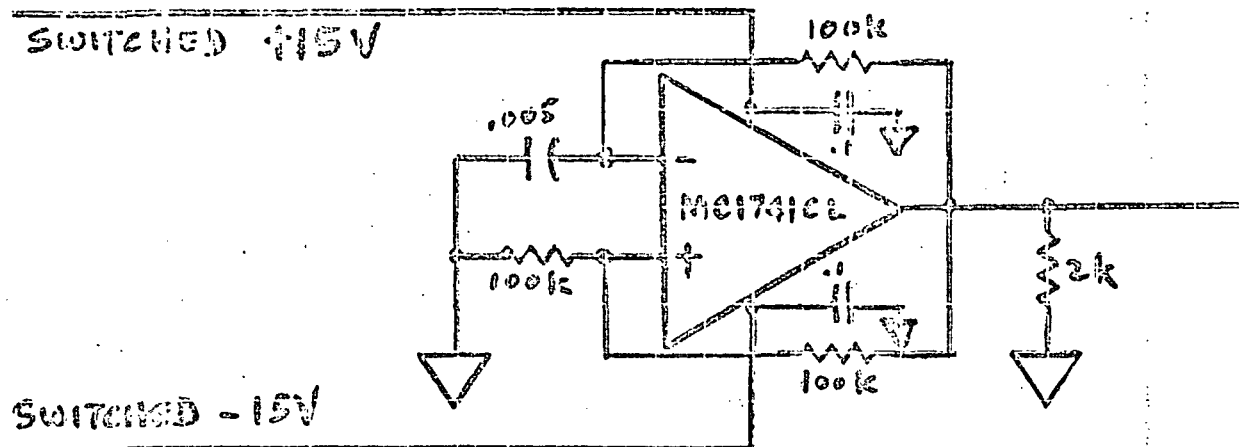
For signal/noise ratio and crosstalk considerations, each mic signal will be stepped up by a gain of 6. Thereafter, all signal manipulation will be at a gain of 1 until the final amplifier stage, which will have a gain of approximately 2.5.

A gain of 1 will eliminate any intermediate variations within the audio system. DC errors due to input bias currents within the op-amps will be negligible. FET analog gates (IH 5009) will be used for all necessary audio switching, isolating, and mixing.

The following describes typical circuits of the audio system design. Numbers correspond to those on the illustrations.

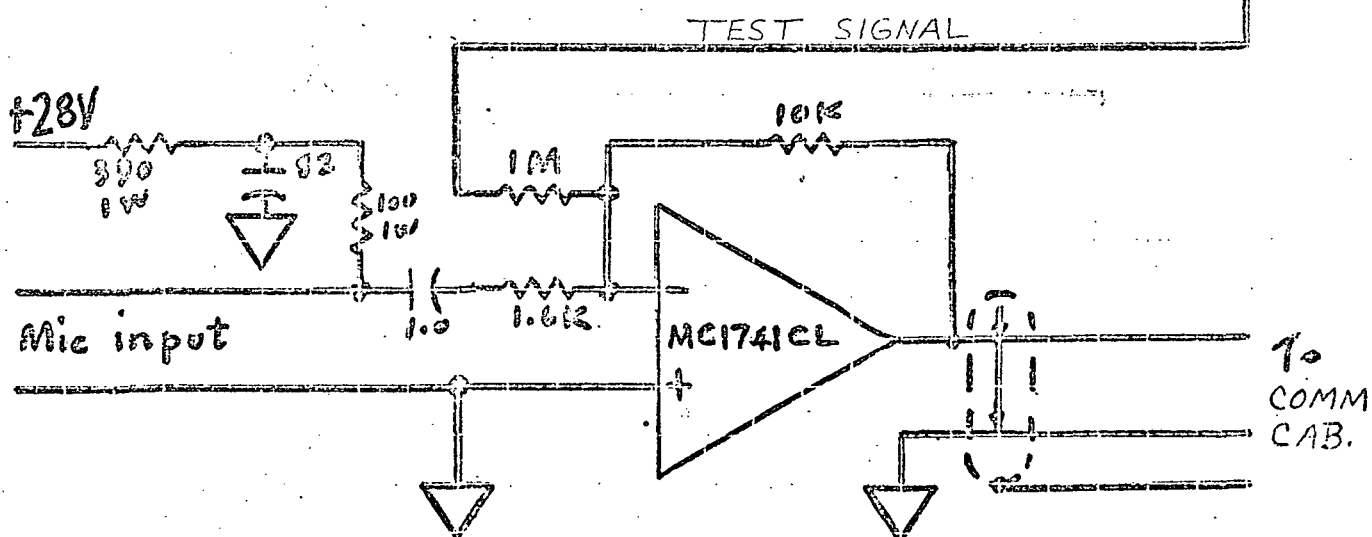
1. An audio tone source is recommended for test purposes. Therefore, a simple square wave oscillator at a frequency of approximately 1 KHZ will be incorporated at each panel. (Figure 4.4.5-6). The tone will be made available only as desired by switching the power to the op-amp from a test panel.

2. Mic Pre-Amp/Driver - Although some headsets come with miniature amplifiers, it will be necessary to boost the Mic Signal



①

1000 Hz Square Wave Oscillator



Microphone <sup>②</sup> Pre - Amp/Driver

Figure 4.4.5-6

before transmitting it to the Communications System Cabinet. This circuit also provides the microphone current, as well as the mixing of the test oscillator output. (Refer to Figure 4.4.5-6.)

3. Differential Receiver/Buffer Amps - Signals from the various panel positions to the Communications System Cabinet, and vice versa, as well as MCC's signals, will be terminated in a differential receiver configuration. This will make use of the high common mode rejection ratio of the op-amps to reject common mode voltages such as noise pickup. It also obviates the use of transformers and provides a low impedance source for all using circuits. Figure 4.4.5-7 illustrates more adequately how this circuit will be applied.

4. Mixer/Driver Amp - This serves to collect the various signals to a particular audio control panel and provides a low impedance driver to the panel positions. (Figure 4.4.5-2.)

5. Mixer - Many schemes have been employed in the past to switch and/or mix signals, ranging from the use of transformers and relays to discrete FET's. This application of the IH5009 brings together many desirable features: high noise immunity, very low cross-talk (typically 120 dB), constant load impedance, compactness, and ease of cascading. In conjunction with thick film resistors in DIP's, various load impedances can easily be configured as needed. (Figure 4.4.5-8.)

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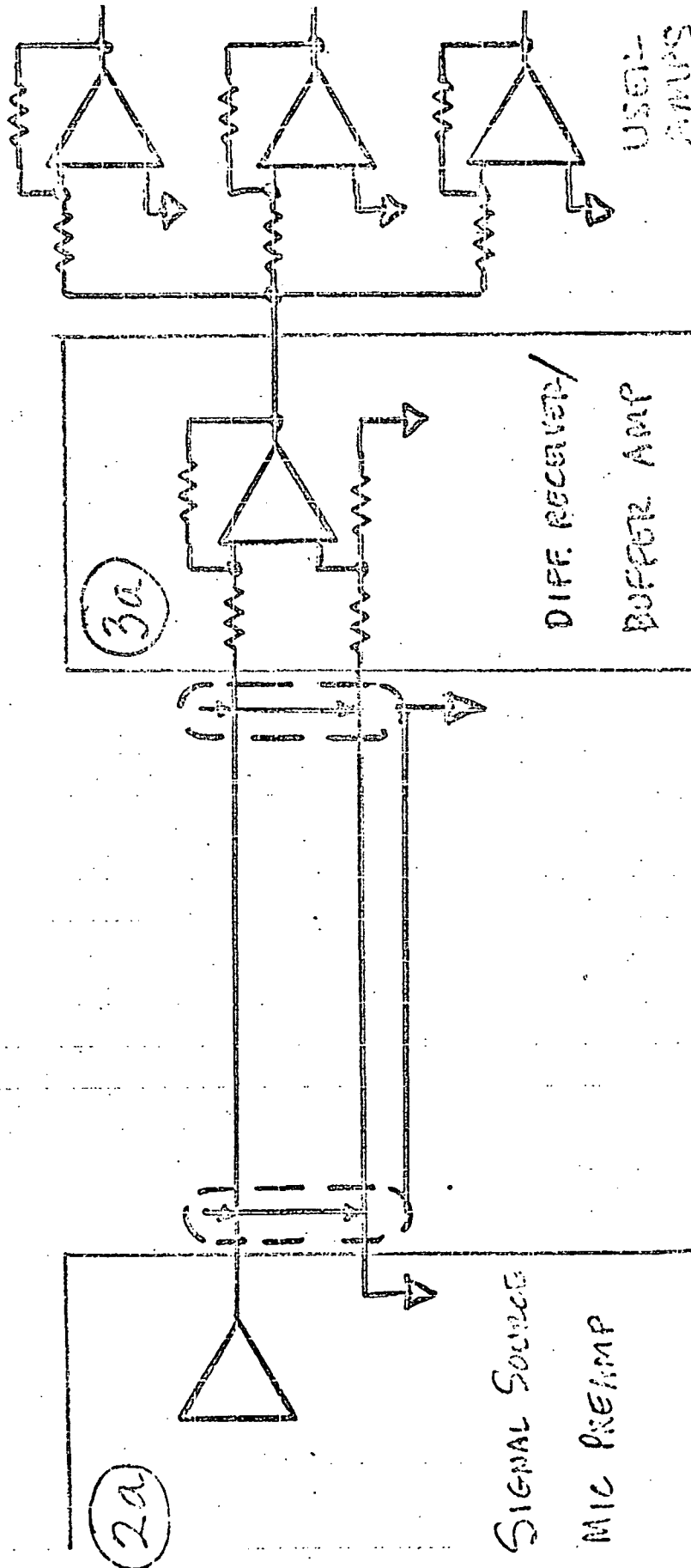


Figure 4.4.5-7  
DIFFERENTIAL RECEIVER BUFFER AMP

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6. Audio Amplifier - This configuration will vary little from the suggested application information. The input and feedback components will be scaled to make the overall gain approximately 2.5.

7. Inverter/Buffer - To be consistent with the approach to ground system isolation inverters will be used to isolate the DCE ground from the audio ground system. (Items 6 & 7, Figure 4.4.5-8.)

#### 4.4.5.7 Caution and Warning Tones

The caution and warning tones will be generated by a fixed frequency oscillator (1 KHZ). The tones will be fed through computer controlled FET switches to Voltage Controlled Attenuators (VCA) and then summed at an amplifier.

The computer controlled VCA's adjust the volume of the tones while the FET's control the interrupt rate. The desired caution and warning signals can then be chosen by varying the volume levels and the interrupt rates of the tones. (Figure 4.4.5-5 )

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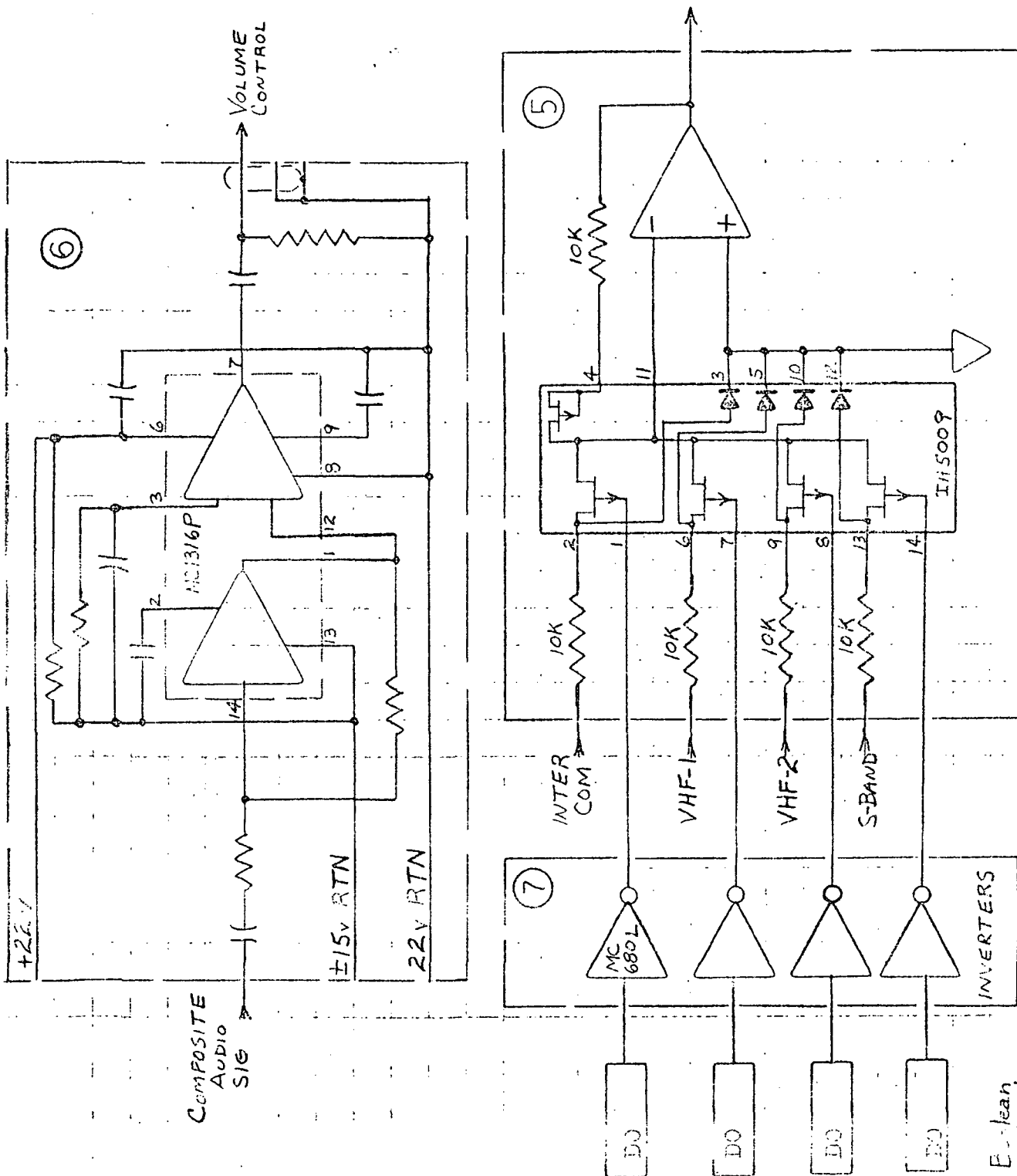


Figure 4.4.5-9  
Detail Layout SMS Audio





## 5.0 Fixed Base Crew Station Equipment

The equipment requirements of the FBCS are defined in Figure 5-1. The requirements of each major area are as follows:

a) Crew Station - The crew station will be compatible with the forward visual system and aft visual system and provide an active hi-fidelity replica of the entire upper crew station including Commander, Pilot, payload handling, mission specialist and manipulator control work stations.

### b) Forward Visual System

- (i) Full Field of View Display System
- (ii) Capable of all scene requirements including Launch, Launch Abort, Orbital, Rendezvous, Docking, Station Keeping, Payload Operations, Re-entry, Approach and Landing.

### c) Aft Visual

- (i) Full Field of View Display System
- (ii) Capable of all scene requirements except Launch, Launch Abort, Re-entry Approach and Landing.

d) On-Board Computer Equipment - This equipment will provide the capability of simulating the vehicle's on-board computers to include:

- (i) Data Processing System
  - a) Primary CN&C (2)
  - b) Backup GN&C

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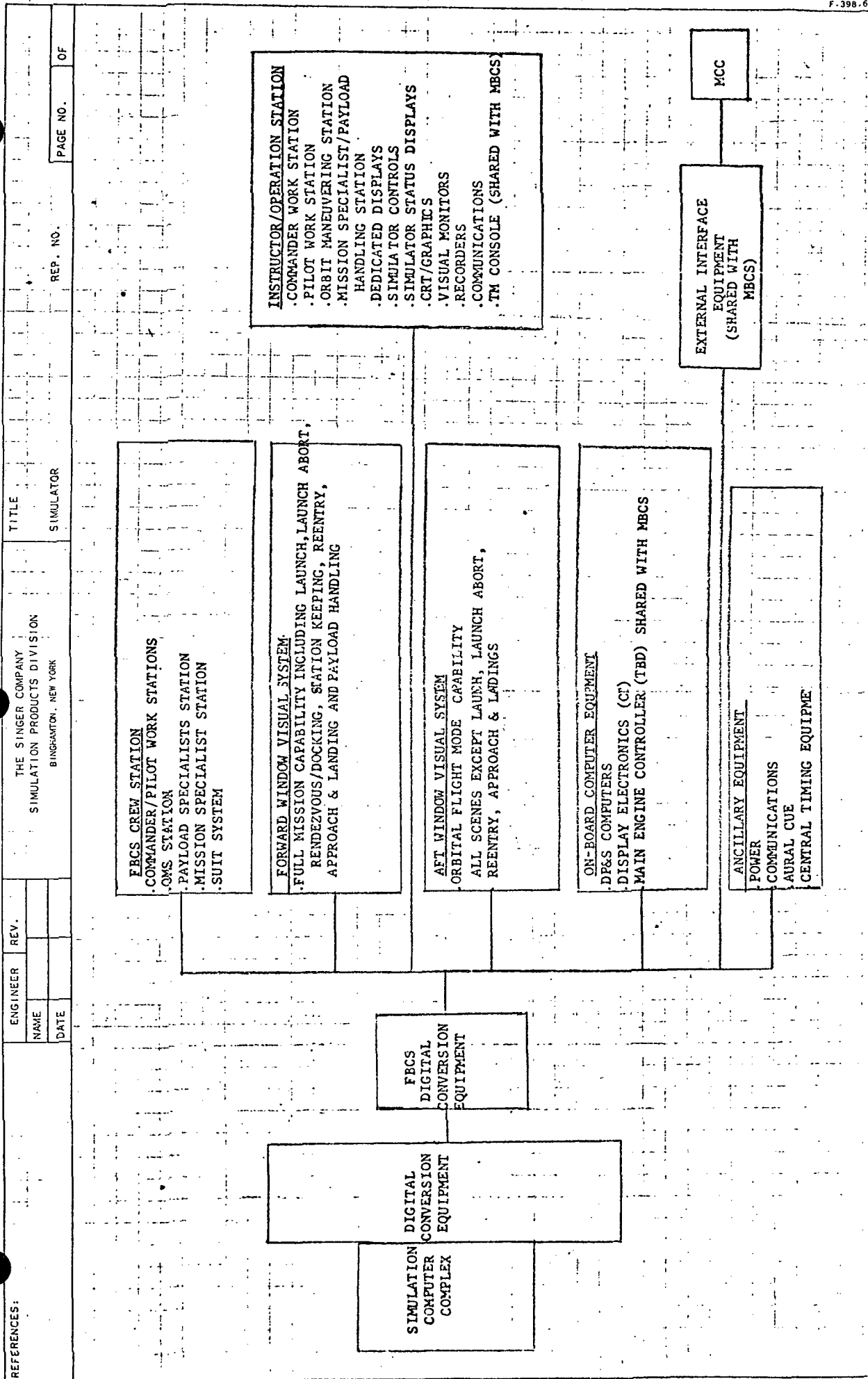


FIGURE 5-1 FIXED BASE CREW/INERTIAL SIMULATOR EQUIPMENT REQUIREMENTS

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c) Auxilliary Processors (2)

(ii) Main Engine Controller Computers (shared with MBCS)

For the purpose of this report, the simulation will be capable of handling the redundancy of computers and the resulting switch-overs for malfunction situations and the utilization of flight software.

e) Instructor Operator Station - The instructor operator station for the FBCS will be capable of providing the following capabilities:

- (i) Commander Work Station
- (ii) Pilot Work Station
- (iii) Orbit Maneuvering Station
- (iv) Payload Specialist Station
- (v) Mission Specialist Station
- (vi) Dedicated Monitoring Displays
- (vii) Simulator Status Displays
- (viii) Simulator Controls
- (ix) CRT/Graphic System
- (x) Visual Monitors
- (xi) Data Recording Equipment
- (xii) Communications Equipment
- (xiii) Telemetry Console (shared with MBCS)

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The design will be such as to enable three instructors to accomplish training in the non-integrated mode.

f) External Interface Equipment - Equipment which will enable the FBCS to operate in a closed loop mode with MCC will be provided.

g) Ancilliary Equipment - Ancilliary Equipment requirements fall into a variety of areas namely:

(i) Aural Cue - Equipment will be provided to duplicate the sound heard within the orbiter vehicle during its missions.

(ii) Power - Equipment will be provided to enable building power to be converted to the power types and levels required to operate the MBCS equipment.

(iii) Communications - Equipment will be provided to enable communications between the simulated crew station, IOS, Maintenance areas and MCC.

(iv) Central Timing Equipment - Timing signals will be provided to enable the FBCS, SCC and MCC to operate in a synchronized manner.

h) FBCS Digital Conversion Equipment - Under the present ground rules the DCE is to be GFP. Therefore no unique FBCS DCE requirements are anticipated. However, the overall SMS DCE design is discussed in Section 7.0.

### 5.1 Facility Layout

The Fixed Base Crew Station and visual system will be positioned alongside the Motion Based Crew Station, oriented to optimize the space allocated to the SMS in the Houston facility. The arrangement is further described in Section 3.1.

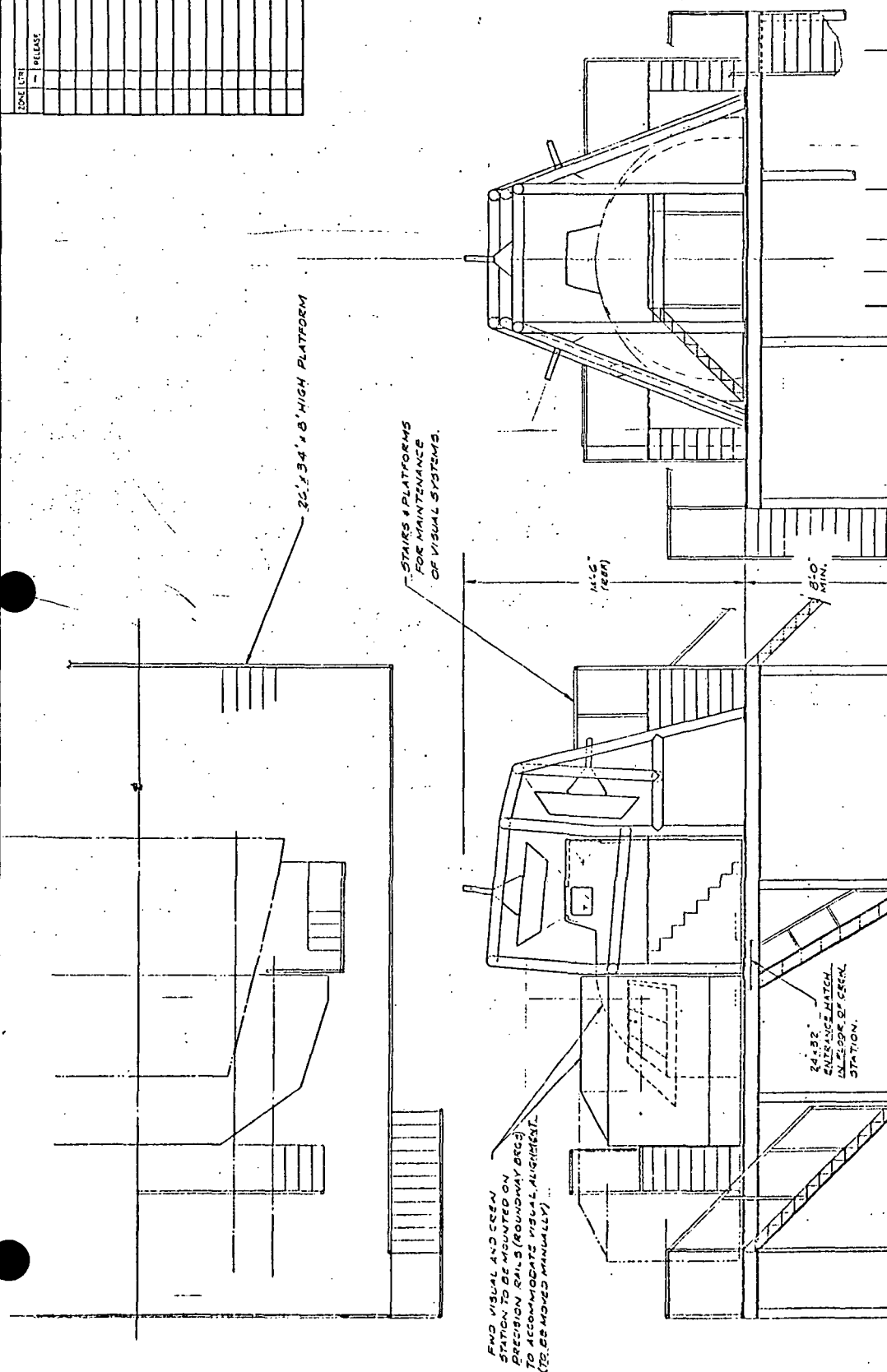
### 5.2 Crew Station

The crew station of the fixed base simulator will be a high fidelity replica of the interior of the entire upper floor of the orbiter crew stations extending longitudinally from station 411 to station 560, and vertically from W.L. 406 to the top of the cupola, W.L. 516.

The crew station will be fabricated in two sections for ease of handling and fabrication, joined at station 478. Thus the aft station will be 86" wide x approximately 156" long, x approximately 110" high. The cupola will be removable to reduce the height to approximately 91" to satisfy the shipping size specification of 7'4" x 8' x 16'.

The forward section will be essentially identical to that of the motion based simulator except that it will include the normal ingress/egress hatch and the interfloor hatch, neither of which is included on the motion based crew station, where entrance is made at the rear.

This entire crew station will be mounted on a raised platform such that it will nest within the visual display system and can be repositioned on the platform as required to permit visual alignment of either the forward or aft visual systems. The concept is shown in Figure 5.2-1.

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This raised platform will accommodate a ladder and permit ingress and egress thru the floor hatch as accomplished in the spacecraft.

#### 5.2.1 Crew Station Structure

The structure for the crew station will be a composite structure of welded aluminum base frame and a shell of molded fiberglass construction, which bolts to the base frame. See Figure 5.2.1-1.

The aft shell is open at the top to receive the separate cupola, approximately 44" wide x 57" long x 22" high which contains the four cupola windows and the controls and displays within that section. As a separate section this creates a modularity to facilitate modification, and to satisfy the package size requirements of the specification. The cupola will be fabricated of molded fiberglass and metal framing. Separate moldings will cover the mounting flanges and restore the simulation of the spacecraft interior in that area.

The seats, seat mounting and tracks will be spacecraft items with modifications to accommodate the repetitive operations typical of simulator use. The consoles, shelves and lining will be installed to duplicate the spacecraft appearance from the interior though the mounting structure will be simplified to reduce weight consistent with maintaining strength incident to the loads imposed by shipping since the fixed base simulator will not be subjected to the accelerations encountered in the flight vehicle.





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The linings, lights, air outlets, etc., will either be spacecraft parts or simulated parts as determined by availability and cost. The choice of spacecraft components may still be cheaper since the engineering, tooling and fabrication costs must be amortized over relatively few items.

The window framing will be designed to simulate the spacecraft appearance as visible to the crew but the special glass will be replaced with plexiglass.

#### 5.2.2 Control Loading

Control loading for the fixed base simulator will be identical to that of the motion based simulator (Para. 4.2.2) except for the inclusion of the additional controls at the Remote Manipulator Station. Controls requiring hydraulics will use the hydraulic power of the motion based simulator.

#### 5.2.3 Crew Station Air Conditioning

The air conditioning system will be the same as for the motion based simulator, Para. 4.2.3, except that the routing of ducts in the aft section will be modified to achieve the high fidelity which was compromised on the motion based simulator. Also the inlet duct installation will be simplified since it will not be subject to the excursions of the motion system.

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#### 5.2.4 Crew Station Suit System

The suit system will be identical to that of the motion based simulator, paragraph 4.2.4, except as modified to include the connections at the R.M. Station. Both systems will share common tanks, and cooling and drying components.

### 5.3 Fixed-Base Simulator IOS Complex

Because of the number of crew positions to be trained on the SMS, the IOS will be designed in modular form. The following IOS modules will comprise the fixed-base IOS: (1) Commander and Pilot, (2) Telemetry, (3) Orbital Maneuvering Station, and (4) Mission and Payload Specialist. The Telemetry Operator Station will function for both the fixed-base and motion base IOS, and will be provided with the MBCS.

In addition to the IOS consoles, the fixed-base IOS complex includes:

- a. One X-Y recorder
- b. Three eight-channel time history X-T recorders
- c. Four castored, fully adjustable, swivel chairs
- d. One hard-copy print-out device.

#### 5.3.1 Commander-Pilot IOS

The Commander-Pilot IOS for the fixed-base simulator will be identical to the IOS for the motion-base simulator. (Reference Figure 4.3 -1). This IOS will include all the features and provide the instructor with the same capabilities offered in the motion-base simulator. Slight modifications will appear on those console panels containing controls for the motion-tilt system. In the case of the fixed-base simulator, those controls will be eliminated.

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### 5.3.2 Orbital Maneuvering Station IOS

The Orbital Maneuvering Station (OMS) IOS is one of the IOS modules which comprise the fixed-base simulator IOS complex (Reference Figure 5.3-1 ). The station is designed to be manned by one instructor. It is assumed that since the vehicle commander is responsible for the tasks performed at the OMS, the Commander instructor will also serve as the instructor at this IOS. Based on this premise, the OMS IOS will be located adjacent to the Commander's IOS.

The OMS IOS will be vertically stacked similar to the Commander-Pilot IOS. The upper segment will be canted downward at a 30 degree angle from the vertical. The center segment will be vertical, and the lower segment will be inclined 45 degrees from the horizontal, and joins the horizontal writing surface. With this design, the instructor's line-of-sight will be approximately perpendicular to the center of each tier.

The writing surface will be 16 inches deep to provide adequate space for reference materials and for writing. The height of the writing shelf above the floor is  $25\frac{1}{2}$  inches (in conformity with MIL-STD-1472 and MSFC-STD-267A) which allows the keyboard unit to be at a comfortable level, and yet provides ample knee room for the instructor.



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The upper tier of the IOS will consist of a visual monitor and two TV monitors which are repeaters of those located at the OMS. The visual monitor will permit the instructor to monitor the visual scenes portrayed on the cupola windows. The center tier will consist of an alphanumeric CRT and dedicated instruments. Additional space is provided on this panel for future growth. The lower tier will house the controls required for operation of this station. A keyboard unit will be located at the OMS IOS which would operate in conjunction with the CRT unit.

#### 5.3.2.1 CRT Display/Keyboard Units

The keyboard/display unit will operate identically to those described previously in 4.3.1.1.1, and the same keyboard action will be used to select a display or modify a value stored in the computer. The top line of the CRT will always contain the following data:

- a. A one-or two-character display mnemonic identifying the display.
- b. Symbols indicating the ground station in contact with the vehicle; if none are in contact, LOS is displayed.

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- c. Mission elapsed time
- d. Simulated Greenwich mean time

The following CRT pages, identical to those available at the Commander-Pilot IOS, will be provided at the OMS IOS:

- a. Event Time Monitor
- b. Panel Displays (excluding those provided by dedicated displays)
- c. Energy Management Predictor
- d. Malfunction Insertion and Display
- e. Circuit Breaker Status
- f. Crew Station Setup Verification
- g. Active Malfunctions and Tripped Circuit Breakers
- h. Mission Parameters and Summary Display
- i. Interface Data Stream and Telemetry Monitoring
- j. Enroute and Approach Display
- k. System Schematic Displays
- l. Programmed Demonstration Display
- m. Training Exercise Display
- n. Performance Monitor Display
- o. External Environment
- p. Simulator Reset
- q. Simulator Status



A description of the above displays and the method by which the displays are called up is as outlined in 4.3.1.1.1.

At the OMS IOS, a separate CRT is not dedicated to the Event Time Monitoring page. This page will provide a chronological listing of the most recent crew actions. The most recent crew action will be displayed on the top line of the CRT. As the next action takes place it will occupy the first line and the previous action will be moved to the second line. When the CRT page is filled, a new action will cause the last line on the page to be dropped from the display. Each line will contain the following data:

- a. The name of the control manipulated
- b. The action taken: For a non-momentary switch, the new position will be displayed. For a momentary switch or a continuous control, the direction of the most recent motion would be shown.
- c. The time at which the switch action occurred.
- d. The mnemonic of the system page involved.

To call up the Event Time Monitor page, the instructor will depress the "PAGE SELECT" key followed by the keys of the mnemonic which identifies the page.

#### 5.3.2.2 Dedicated Instruments

The following instruments located at the OMS will be repeated at the IOS to permit the instructor to monitor the trainee's performance (Reference Figures 5.3-2 and 5.3-3):

## CAUTION AND WARNING

--	--	--	--	--	--	--	--	--	--

## RIGHT BOOM

SHOULDER

ELBOW

WRIST

PIVOT

ROLL

PIVOT

ROLL

TILT

PAN

ROLL

--

--

--

--

## LEFT BOOM

SHOULDER

ELBOW

WRIST

PIVOT

ROLL

PIVOT

ROLL

TILT

PAN

ROLL

--

--

--

--

BOOM POSITION INDICATOR PANEL

FIGURE 5.3-2

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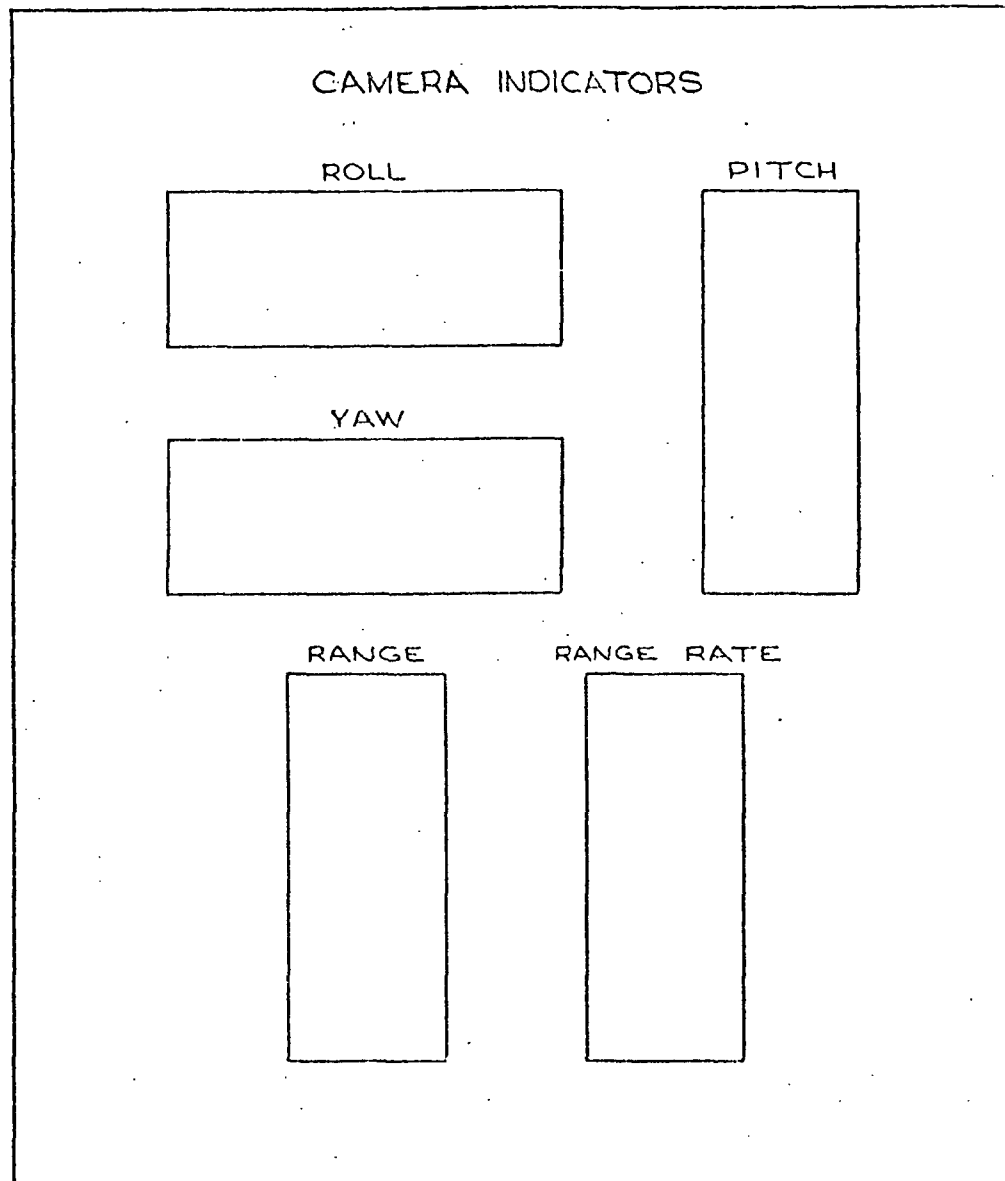
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CAMERA INDICATOR PANEL

FIGURE 5.3-3

- a. Right Boom Position Indicator
- b. Left Boom Position Indicator
- c. Camera Attitude Indicators
- d. Camera Range Indicator
- e. Camera Range Rate Indicator
- f. Caution and Warning Indicators
- g. Monitor 1
- h. Monitor 2

#### 5.3.2.3 Simulator Control and Display

The IOS control panel will contain the necessary controls and indicators for operation of the IOS. Sufficient controls will be provided to operate the station individually as a part task trainer or in concert with the other IOS's for integrated crew training. The following control panels will be provided at the IOS:

- a. Operate Controls
- b. Communications Controls
- c. Visual Window Select Controls (Reference Figure 5.3-4).
- d. Sound/Lighting Controls

##### 5.3.2.3.1 Operate Control Panel

The Operate Control Panel will contain all the necessary controls and indicators to operate the OMS of the simulator. The controls contained on this panel will be identical to those controls contained on the same panel at the Commander-Pilot IOS for the fixed-

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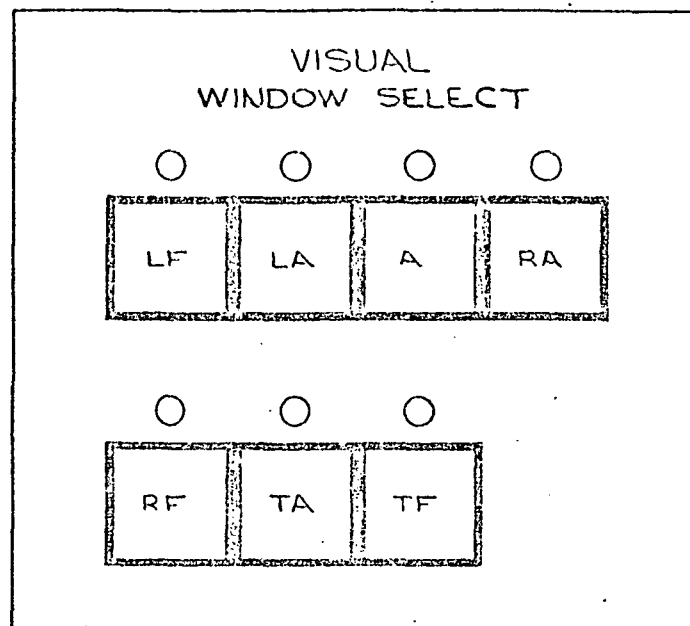
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VISUAL WINDOW SELECT PANEL

FIGURE 5.3-4

base simulator. A functional description of the controls is the same as discussed in 4.3.1.3.2.

#### 5.3.2.3.2 Communications Control Panel

This panel will contain all the necessary controls for the instructor to communicate with the trainee, other instructors, and personnel in support of the training exercise. The controls on this panel will be the same as those on the Commander-Pilot IOS console for the fixed-base simulator and are described in 4.3.1.1.1.7.

#### 5.3.2.3.3 Visual Window Select Panel

This panel will provide the instructor with the necessary controls to select a scene being portrayed in one of the seven cupola windows. Selection of the cupola window to be displayed on the Visual Monitor will be made through a switch-light. Tell-tale lights located above the switch-light will indicate the cupola window at which a visual scene is being portrayed. The following switch-lights, when activated will call up the appropriate cupola window scene on the visual monitor.

"LF" - Left forward

"LA" - Left aft

"A" - Aft

"RA" - Right aft

"RF" - Right forward

"TA" - Top aft

"TF" - Top forward

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5.3.2.3.4 Sound/Lighting Control Panel

This panel will contain the same controls and indicators presented on the Commander-Pilot IOS. Their function is described in Section 4.3.1.1.3.8.

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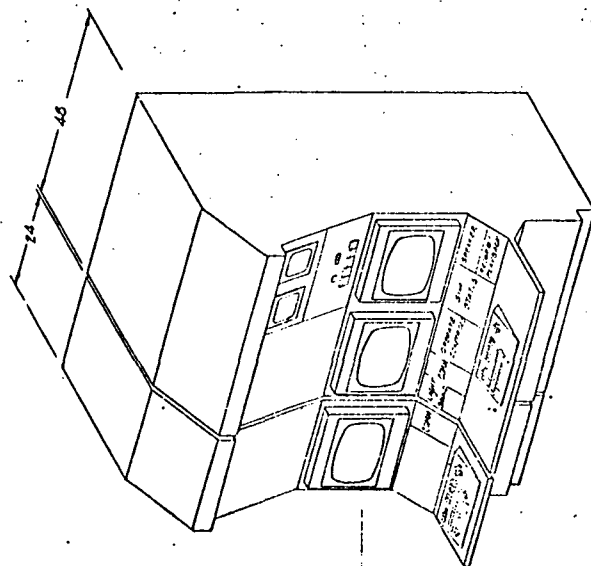
### 5.3.3 Mission Specialist/Payload Specialist IOS

The Mission Specialist/Payload Specialist (MS/PS) IOS is designed to be manned by one instructor. The instructor will be provided with all the controls necessary to operate the simulator in a non-integrated mode or for mission rehearsals integrated with MCC. The instructor console will integrate two CRT display units, a keyboard unit, TV monitors, dedicated displays, a control panel used for functions not accomplished with the keyboard unit, and an audio panel to provide the necessary communications functions.

The MS/PS IOS will be vertically stacked similar to the Commander-Pilot IOS (Reference Figure 5.3-5). The upper segment is canted downward at a 30 degree angle from the vertical. The center segment is vertical, and the lower segment is inclined 45 degrees from the horizontal, and joins the horizontal writing surface. With this design, the instructor's line-of-sight will be approximately perpendicular to the center of each tier.

The writing surface will be 16 inches deep to provide adequate space for reference materials and for writing. The height of the writing shelf above the floor will be 25½ inches which allows the keyboard unit to be at a comfortable level and yet provides ample knee room for the instructor.

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MS/B3 AND TELEMETRY CONSOLES  
FOR FDCS SIMULATOR  
FIGURE 53-5

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The upper tier of the IOS consists of two TV monitors which are repeaters of those located at the Mission Specialist Station. This tier also provides space for dedicated instruments. The center tier contains two alphanumeric CRT's, and the lower tier includes those controls required for operation of this station. At the time of this report, no diagrams were available which describe the configuration of the Payload Specialist's panel within the SSV. However, space is provided at the IOS for TV monitors and dedicated instruments which may be required for this crew position.

#### 5.3.3.1 CRT Display/Keyboard Units

The MS/PS IOS will provide the instructor with two CRT display units. Either CRT will have the capability of displaying alphanumeric or graphic data depending upon the page which is called up. The keyboard unit, centrally located on the writing surface between the two CRT's will operate identically to those located at the Commander-Pilot IOS and described above in 4.3.1.1.1, and the same keyboard action will be used to select a display or modify a value stored in the computer.

The following display pages will be available at the MS/PS IOS:

- a. Event Time Monitor
- b. Panel Display (excluding those provided by dedicated displays)
- c. Energy Management Predictor

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- d. Malfunction Insertion and Display
- e. Circuit Breaker Status
- f. Crew Station Setup Verification
- g. Active Malfunctions and Tripped Circuit Breakers
- h. Mission Parameters and Summary Display
- i. Interface Data Stream and Telemetry Monitoring
- j. Enroute and Approach Display
- k. System Schematic Displays
- l. Programmed Demonstration Display
- m. Training Exercise Display
- n. Performance Monitor Display
- o. External Environment
- p. Simulator Reset
- q. Simulator Status

A description of the above displays and the method in which the displays are called up on the CRT is the same as outlined in 4.3.1.1.1.1 through 4.3.1.1.1.16.

At the MS/PS IOS a separate CRT is not dedicated to the Event Time Monitoring page as is the case at the Commander-Pilot IOS. This page and its contents are as described in 4.3.1.1.1.1.

#### 5.3.3.2 Dedicated Instruments

The following instruments located at the Mission Specialist station of the crew cabin will be repeated at the MS/PS IOS. This

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listing does not include dedicated instruments for the Payload Specialist station which are TBD.

- a. Caution and Warning Indicators
- b. Master Alarm Indicator
- c. Event Time Meter
- d. CRT-1 Monitor
- e. CRT-2 Monitor

#### 5.3.3.2.1 Simulator Status Panel

The Simulator Status Panel provides a visual indication to the instructor of the status of the simulator and its associated sub-systems. The panel is located in a central location of the IOS console to facilitate convenient access and ease of viewing by the instructor. The following is a description of the controls located on this panel.

##### Power System Status

"MIP" - This indicator, when illuminated, represents that maintenance is in progress.

"ON" - When all power required from the main power source is available to the simulator for its operation, this indicator will illuminate.

##### DCE Status

"READY" - Illumination of this indicator denotes that the DCE unit is tied into the simulator and "READY" for operation.

### Computer Status

"FAULT" - The computer fault light will indicate when a fault has been detected. When the source of the fault is removed, the light will be extinguished. If the fault is transient, the light will not stay on. The computer fault indicator is only active when the computer is off-line and not operating in a mission mode.

"READY" - This indicator, when illuminated, signifies that the computer is tied into the simulator and the simulator is "READY" for operation.

#### 5.3.3.2.2 Operate Control Panel

The Operate Control Panel contains the necessary controls and indicators to operate the Mission and Payload Specialist station of the simulator. The controls contained on this panel are identical to those controls contained on the same panel at the Commander-Pilot IOS for the fixed-base simulator. A functional description of the controls is the same as discussed in 4.3.1.3.2.

#### 5.3.3.2.3 Communications Control Panel

This panel contains all the necessary controls for the instructor to communicate with the trainee, other instructors, and personnel in support of the training exercise. The controls on this panel are the same as those on the Commander-Pilot IOS for the fixed-base simulator and are discussed in 4.3.1.1.1.7.

#### 5.3.3.2.4 Lighting/Sound Control Panel

This panel contains the same controls and indicators presented on the Commander-Pilot IOS. Their function is described in 4.3.1.1.3.8.

#### 5.3.3.2.5 Record/Playback Control Panel

These controls, in conjunction with the keyboard unit are used to record the trainee's performance and play it back at a subsequent time. This feature will also permit the instructor to demonstrate a preprogrammed training task to the trainee. The controls on this panel are the same as those located at the Commander-Pilot IOS for the fixed-base simulator. The function of the controls are described in 4.3.1.1.3.6.

#### 5.3.3.2.6 Speaker Control Panel

A speaker is provided at the MS/PS IOS to monitor the communications conducted at the crew positions in the simulator (Reference Figure 5.3-6). The speaker is supplied in addition to the instructor's headset. The controls and their function are:

"VOLUME" - This control permits the sound intensity of the speaker to be varied.

"SPKR ON" - Activation of this dual-action switch-light permits communications to be heard over the speaker system.

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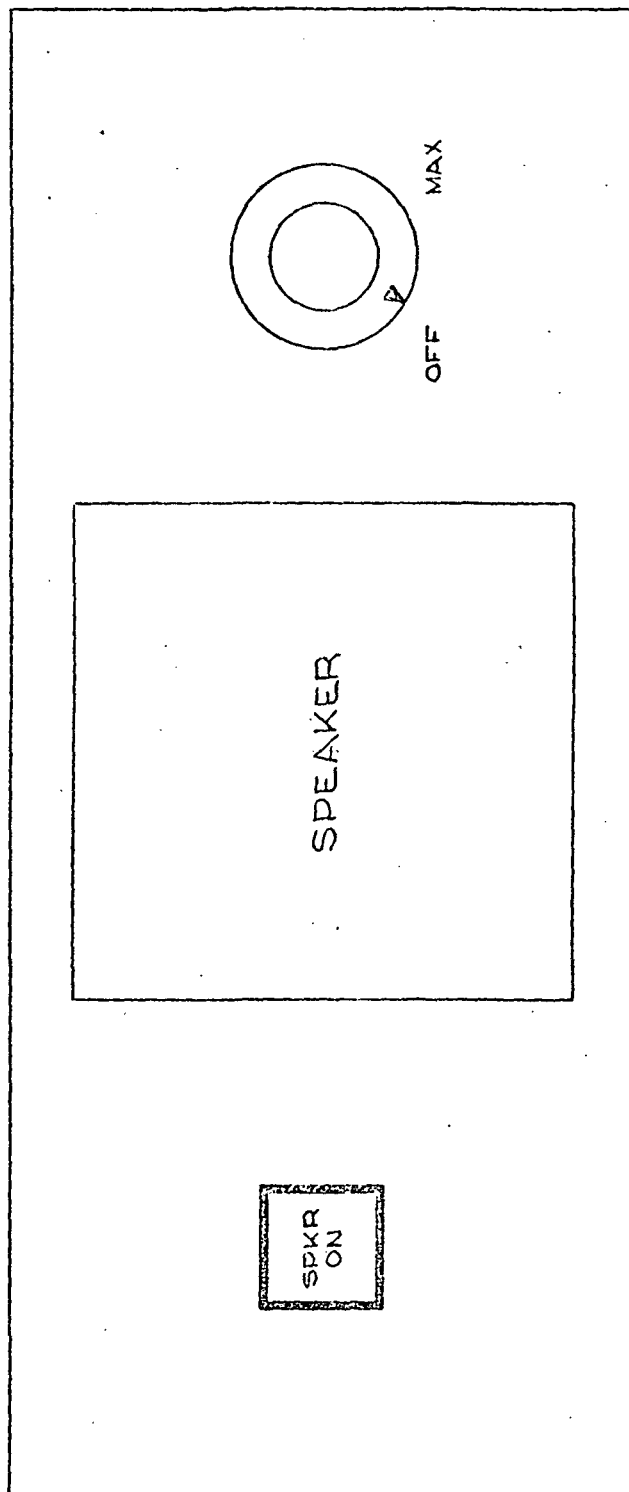
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SPEAKER PANEL, MS/PS IOS

FIGURE 5.3 - 6



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### 5.3.3.3 Simulator Control and Display

The IOS will contain the necessary controls and indicators for operation of the IOS in conjunction with the other IOS's for non-integrated crew training or for mission rehearsals integrated with MCC. The following control panels are provided at the MS/PS IOS.

- a. Simulator Status
- b. Operate Controls
- c. Communications Controls
- d. Lighting/Sound Controls
- e. Record/Playback Controls
- f. Speaker Controls

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#### 5.3.4 Layout Mock-Up

A layout of the instructor area along with the justification for that layout will be provided at the contractor's plant prior to the firm requirements relative to the overall layout. Where major components are duplicated on the console (e.g., CRT displays) only one will be modeled in detail. The model will be as complete as necessary to permit evaluation of the general arrangement and installation of the following equipment.

- a. Location of the IOS's with respect to crew compartment stations
- b. Instructor-operator flight compartment controls
- c. Full scale replica of all cabinets and panels including controls and indicators located in the instructor-operator areas
- d. Instructor chairs
- e. Lighting arrangement
- f. Sample of panel painting and engraving

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5.4 FBCS Ancillary Equipment

5.4.1 Simulator Power Hardware

The SMS complex will have only one main AC power control cabinet. It will be shared by the FBCS and MBCS simulators. The FBCS and MBCS will have separate, but identical DC Power Cabinets. Refer to 4.4.1.

5.4.2 Aural Cue

Refer to Section 4.4.2.

5.4.3 External Interface

Refer to Section 4.4.3.

5.4.4 Central Timing

Refer to Section 4.4.4.

5.4.5 Audio Communications System

The FBCS Audio Communications System will be the same as the MBCS System with one exception. An additional audio control circuit will be added for the OMS. (Figures 5.4.5-1, 5.4.5-2)

Additional IOS communications stations will be as described in Section 4.3.1.1.3.7.

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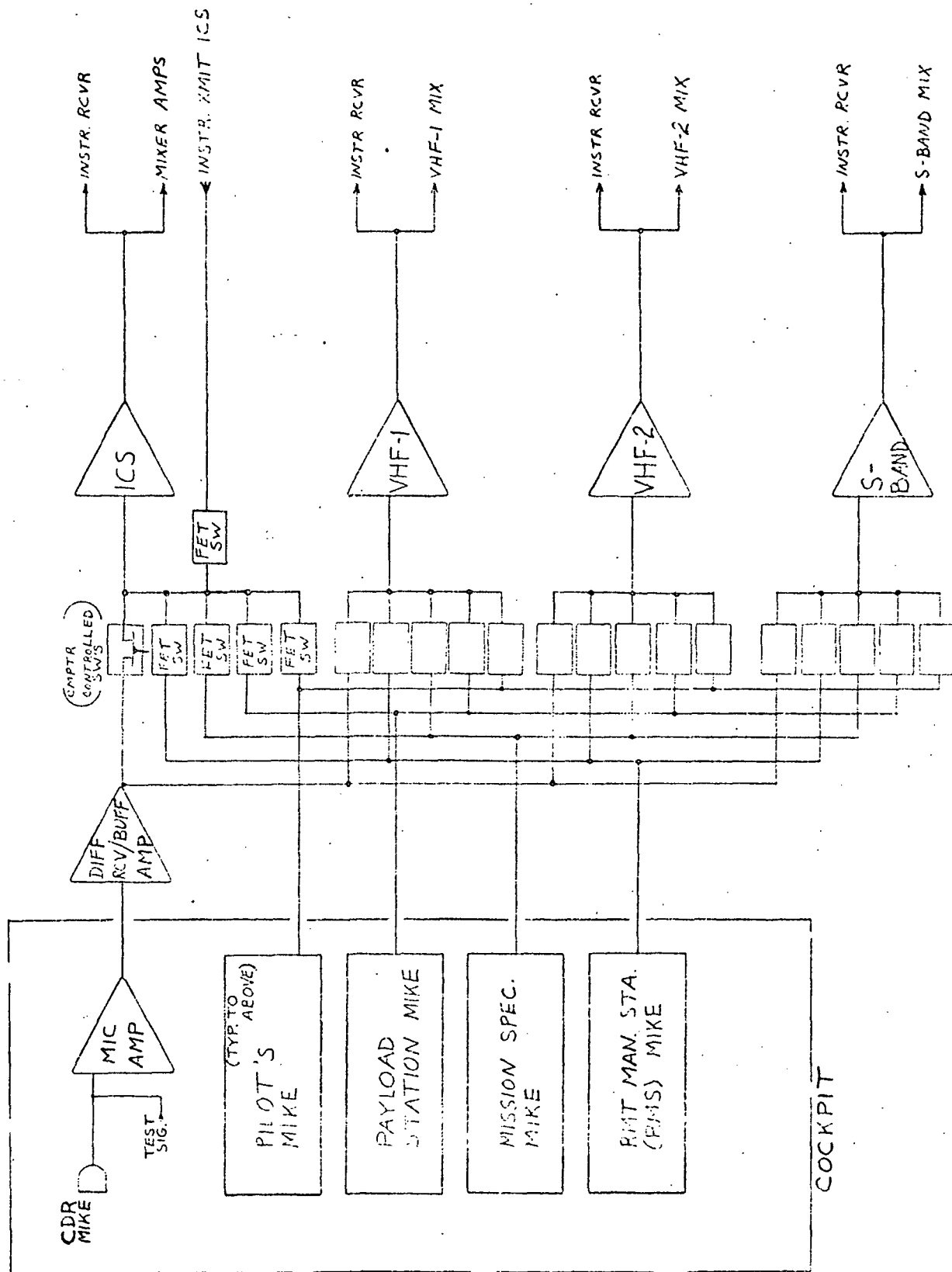


Figure 5.4.5-1 COMMUNICATIONS SYSTEM AUDIO TRANSMISSION



## 6.0 On-Board Computer Simulation

### 6.1 General

On-board computers are utilized in two major systems of the Shuttle vehicle.

One subsystem, entitled the Data Processing and Software Subsystem, includes a total of five digital computers operating in conjunction with associated input/output, data conversion, peripheral, and display and control equipment. This system is dedicated to the tasks of primary and backup guidance, navigation and control, subsystem performance monitoring, and payload control for the manipulators.

A block diagram of this system is shown in Figure 6.1-1.

Each CPU, manufactured by (TBD) is a general purpose computer with a basic full word length of 32 bits. Each provides fixed and floating point hardware arithmetic with half and full word operations. Double precision floating point operations are also provided. The computers have a capability of at least 400,000 full word operations per second in fixed point. Memory cycle time is less than 1.8 microseconds. The computer is capable of addressing 128K words within one full memory cycle time.

Each of these computers interfaces with external Space Shuttle Avionics subsystems through an equipment identified as the Computer Input-Output Unit (IOU). All data communications between each computer and external avionics equipment is accomplished through the IOU.

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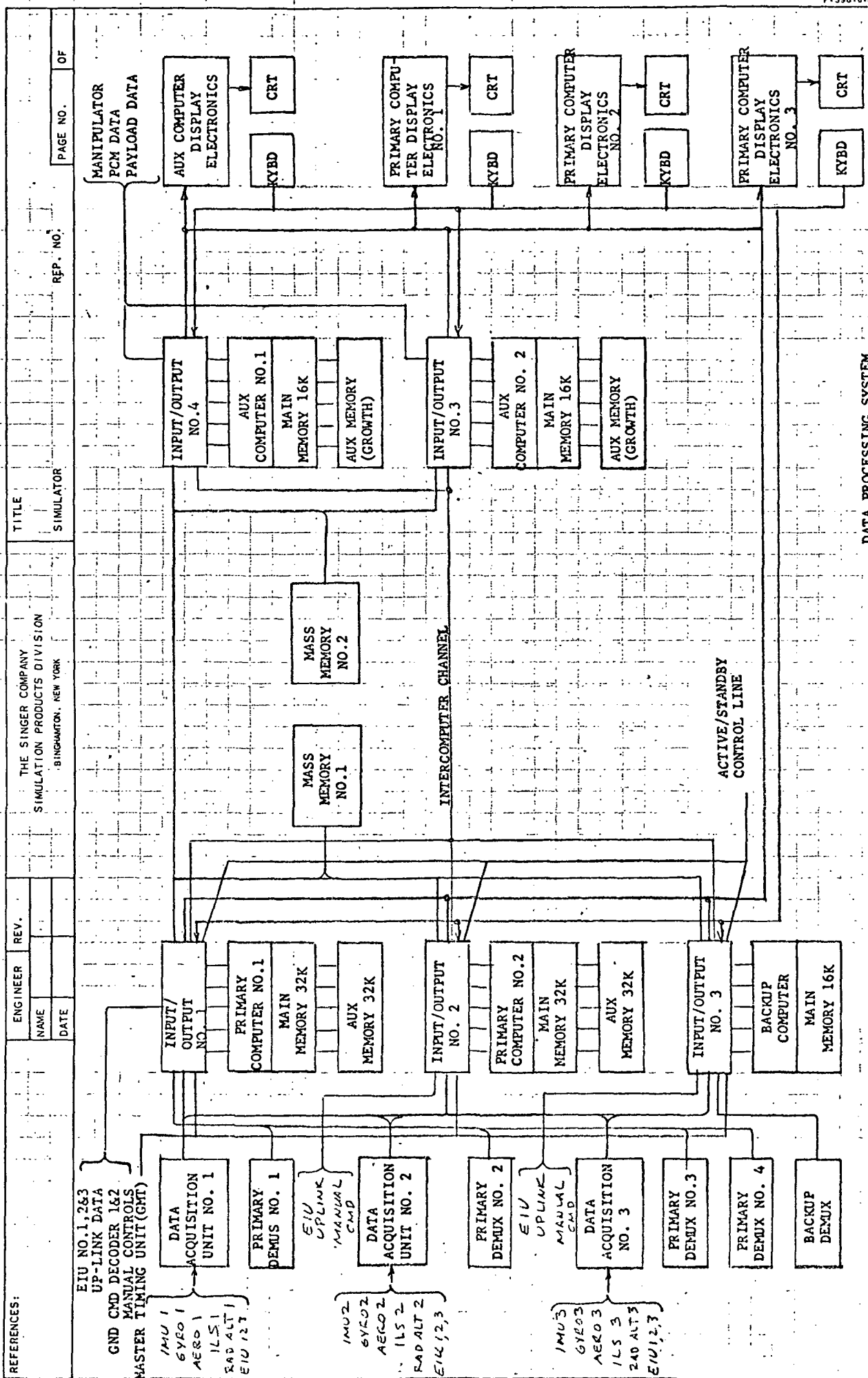


FIGURE 6.1-1 SHUTTLE DPS SYSTEM BLOCK DIAGRAM

DATA PROCESSING SYSTEM

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On the computer side the IOU interface is via two identical interface modules. Each module provides high speed data transfers on half-duplex parallel channels plus additional discrete input and output lines.

On the Avionics equipment side the IOU provides a total input and output channels of 5 different types for interface to the Avionics subsystems and AGE. Table 6.1-1 summarizes these channels by function and type. All data communications between the IOU modules and interfacing Avionics subsystems is in serial format. The data is transmitted to and from the modules in a Manchester II Bi-phase coded serial format at a rate of one megahertz. In the SMS, the crew station CRT Display and Keyboard elements will be provided as GFE. It will be the responsibility of the SMS contractor to integrate the equipment into the crew station and IOS station.

The second Shuttle system incorporating on-board digital computers is the Main Engine Control system where a total of six Honeywell HDC-601 computers are employed in a redundant fashion for control of the firing and gimbaling of the three main engines.

A block diagram of this system is shown in Figure 6.1-2.

The HDC-601 includes a 16-bit parallel binary twos complement arithmetic unit and a plated wire memory with a cycle time of one microsecond. In function and operation the HDC-601 is identical to the Honeywell H-516 digital computer.

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	I Half Duplex IOU	II Simplex Receive IOU	III Simplex Transmit IOU	IV Simplex Receive Continuous	V Simplex Transmit External	Primary and Backup GN&C Computer IOU Channels	Auxiliary Computer IOU Channels
--	----------------------------	---------------------------------	-----------------------------------	--	--------------------------------------	--	--

Telemetry					1	X	
Engine Control			3			X	
Keyboard		5*				X	X
Display Set A			5			X	X
Display Set B			2			X	
Navigation Sensor	3					X	
AGE	1					X	X
Up Data Link				3		X	
Mass Memory	2#					X	X
Flight Control			4PR, 2 B/U			X	
Inter-Computer Data	2#R					X	X
Control Encoder/Coupler	2R					X	
Manipulator Controls	2R						X
PCM Data Master			2				X
Payload Data	1 PR 1 B/U						X
Performance Monitor			2R				
Display Decoder/Coupler			3			X	
Pilots Console,							
IOU Controller		2				X	X
Spare							
Spare							

Table 6.1-1  
DATA PROCESSING SYSTEM INPUT-OUTPUT  
UNIT CHANNELS

\* Party Line  
R - Redundant

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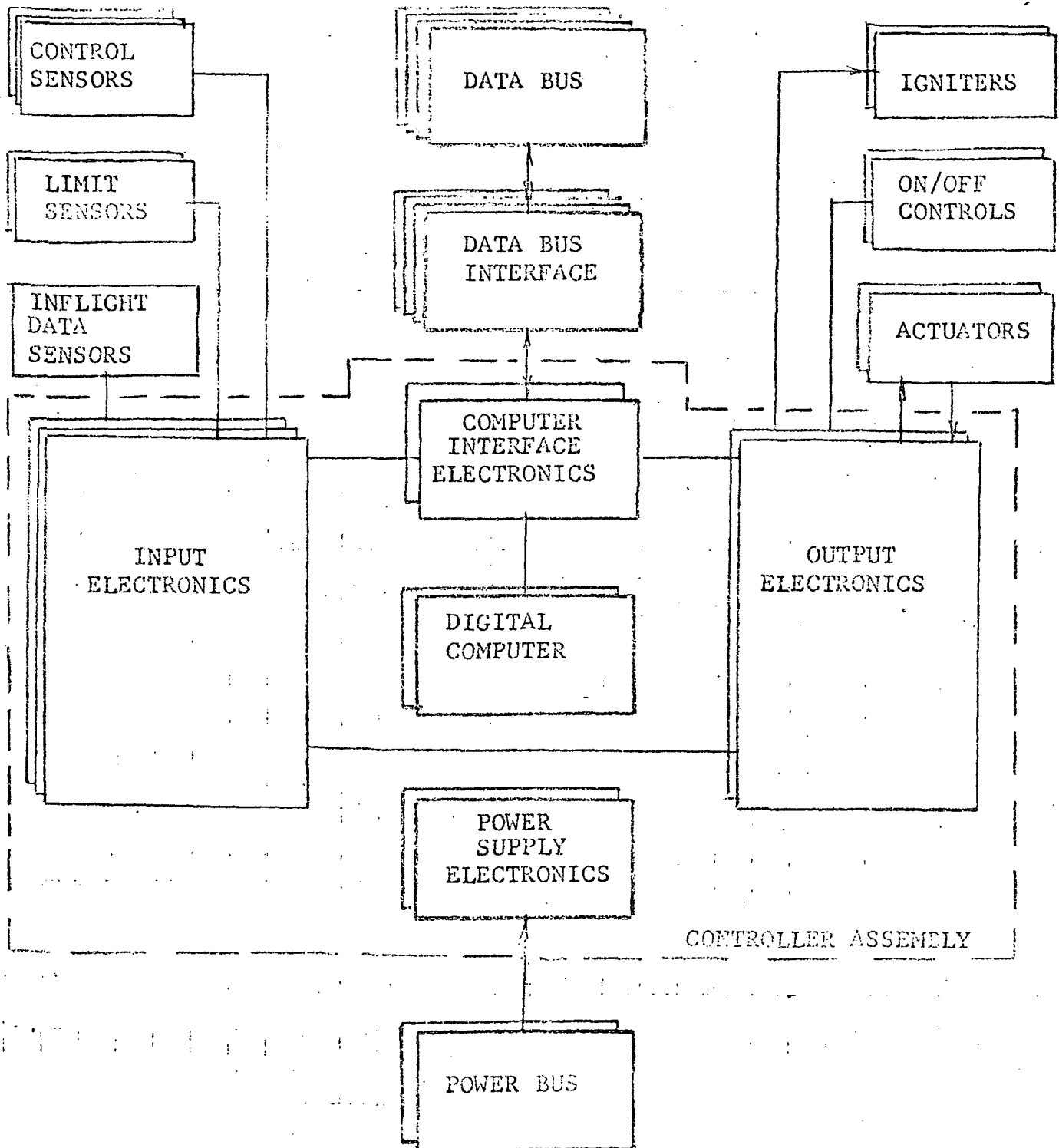


FIGURE 6.1-2

ENGINE CONTROLLER FUNCTIONAL RELATIONSHIPS

## 6.2 Simulation Requirements

### 6.2.1 Data Processing and Software Subsystem

The simulation of the Data Processing and Software subsystem of the Shuttle Vehicle is required to the level that all crew display data and telemetered data responses are extremely realistic for both displayed value and time response to interface signals, commands and switching logic, and simulator modeling. Both the short period and long period accuracy of the simulation must be very high to maintain astronaut confidence in the simulated system and avoid negative training in the use of the system. This will be particularly true during M.C.C. integrated mission training where outputs of the ground computer system are compared with the calculations made in the simulator. Hence the requirement for use of actual OBC flight programs, and an accuracy no less than that of the actual on-board computers. In this case, a 32-bit computer should be utilized for the simulation.

As a minimum, the actual crew station display and control equipment should be used in the simulator to ensure high fidelity display and control. This should include the dual redundant tape readers, if crew procedures dictate the requirement for loading and operating these devices.

The simulated Data Processing and Software subsystem must also interact with the simulator mode functions without degradation.

The reset function in the simulator is provided to enable rapid

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return and restart at mission time points where extensive training is required while skipping over time periods of low activity.

The astronaut should be able to select the active and standby primary computers, and switch to the Backup GN&C computer and realize the same effects as in an actual flight. The requirement to simulate redundancy effects occurs in conjunction with the requirement for simulated malfunctions to train in all backup modes of operation. Simulated malfunctions should be chosen based on failure analysis of real world equipment coupled with the desire to train the astronauts in all backup modes and highly critical procedures to ensure their safety in the real flight.

Use of actual OBC flight software is necessary for reasons of simulation fidelity and to avoid delays inherent in the functional simulation software development and test/verification processes. It is anticipated that software changes to the primary GN&C OBC programs will occur with very short notice. Therefore, the simulator software should be capable of being rapidly updated and reverified, and any equipment or software required to expedite this operation should be provided.

#### 6.2.2 Main Engine Controller

The simulation of the Main Engine computer programs should be of equivalent accuracy, resolution, and iteration rate as in the real world. Data rates and formats to recorders and to the Telemetry system

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must be simulated with high fidelity.

The main engine computer simulation must interact with the simulator mode functions without degradation.

Simulation of the redundancy features is also desired to enable training in backup modes and procedures by inserting malfunctions of one or more elements of the engine controllers.

Selected elements of each engine controller will be malfunctioned to provide crew and MCC training in backup modes and procedures.

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### 6.3 Simulation Approaches

Several methods of real time simulation of airborne and aerospace vehicle on-board computers have been examined in the light of Shuttle vehicle requirements.

Techniques which have been considered include the use of real (or equivalent non-flight qualified) computer hardware, translator/compiler interpreters, and functional simulation.

A brief description of each of these techniques with the advantages and disadvantages of each is discussed in the following paragraphs.

#### 6.3.1 Real Hardware

Use of real (or functionally identical non-space rated) on-board computers in a training device is possible but must include interface hardware to allow communication to and from the main simulation computer(s) and may also require specialized peripheral equipment for computer loading and I/O to associated displays and controls. Figure 6.3.1-1 is a block diagram of the real hardware approach as implemented on the Skylab simulator.

Advantages in the use of an actual (or functionally identical) OBC are as follows:

- 1) The CPU time and core memory loading requirements in the main simulation computer will be reduced.

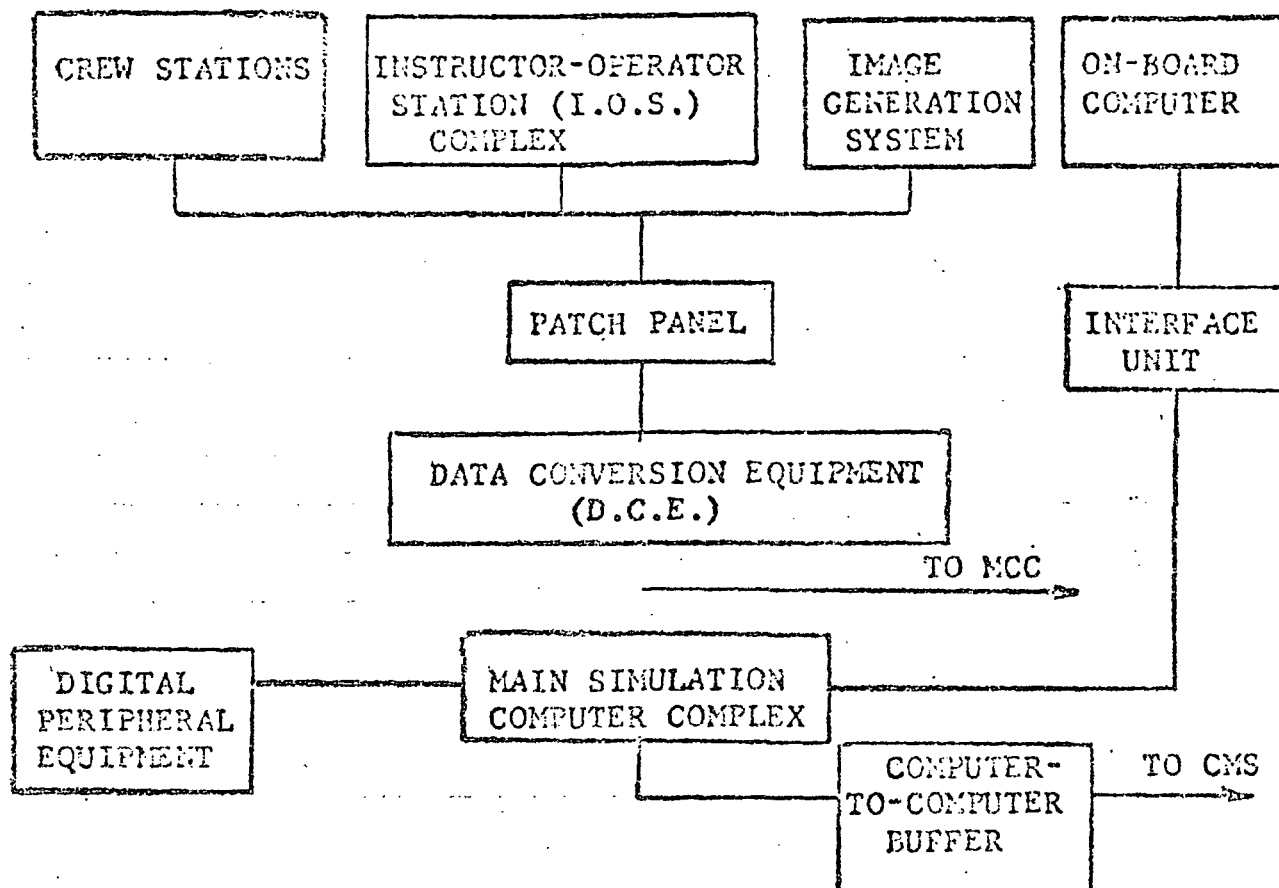


FIGURE 6.3.1-1  
SIMPLIFIED BLOCK DIAGRAM OF SETHLAS SIMULATOR  
INCORPORATING REAL ON-BOARD COMPUTER AND INTERFACE



2) Flight programs may be used without modification.

3) New modified flight programs can be loaded at any time with a minimum of modifications to the main simulation computer load.

4) The effort necessary to maintain correct documentation and configuration control for changes in the flight programs is also minimized.

Use of the real OBC hardware requires the design and development of special interface hardware. This interface hardware may be complex and include signal level conversion equipment, parallel and serial data channels, buffer memories, and time synchronization hardware, depending on the complexity of the OBC I/O and the compatibility with the main simulation computer I/O interfaces. Cost, availability, and delivery schedules of the OBC and interface hardware may be prohibitive. Additional software may also have to be added to the OBC to permit its function in a simulation environment.

Computer hardware functionally identical to the actual flight hardware is presently being used on the Skylab Apollo Telescope Mount Digital Computer (ATMDC) Simulator. The computer used is a non-space rated IBM System 477 Model TC-1 computer with interfacing to an IBM Model 360.

### 6.3.2 Translator

In a translative simulation of a computer, the actual flight program must be preprocessed to convert the flight program to an equivalent simulation computer program. This technique differs from the interpretive simulation in that the instruction decoding is done off-line and each OBC instruction is replaced by one or more simulation computer instructions to perform the same operation.

A translative simulation offers many of the same advantages as use of real OBC hardware in that the simulation is based on the actual flight program coding. Translation is faster in real-time execution than interpretation because the burden of decoding an OBC instruction and substituting simulation computer coding is handled by off-line preprocessing. New modified flight programs may be translated and loaded at any time with negligible effect on the main computer load. Effort necessary to maintain documentation and configuration control for changes in the flight program would be minimized. The translative approach also offers the opportunity for validation of the translated program by comparing its performance with the flight program. Input data used during test runs on the flight program could be made available for similar runs on the translated program. A comparison of outputs from the two programs could be used for detecting errors.

A translative simulation is only feasible if the OBC instruction and the simulation computer instruction sets are similar enough

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to permit translation without an enormous increase in required core memory or impact on execution performance. In addition, the host computer must be sufficiently faster than the OBC which is being simulated to compensate for the increase in code volume brought about by the translation.

### 6.3.3 Interpreter

In an interpretive simulation of an on-board computer, the simulation computer must accept an actual OBC flight program as a data set. The host computer must then execute that flight program "interpretively". The interpretive simulator program must decode each OBC instruction sequentially in real time and then execute a set of host computer instructions to duplicate the requested action. In its purest form an interpretive simulation requires the dedicated use of the host computer. Ideally, this host computer must also be compatible with other computers in the simulation computer complex.

An interpretive simulation of an OBC offers several of the same advantages as use of the real OBC hardware.

- 1) Flight programs may be used without modification.
- 2) New modified flight programs can be loaded at any time with only slight modification to the main simulation computer load.
- 3) The effort necessary to maintaining correct documentation and configuration control for changes in the flight program is minimized.

The interpretive simulation also provides an opportunity for

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effective validation of the interpreted program by comparing its performance with that of the actual flight program. The input data used during test runs on the flight program could be made available for similar runs on the interpreted program. A comparison of outputs from the two programs could be very useful in detecting errors.

In its purest form, an interpretive simulation requires the dedicated use of a host computer. Thus, one or more digital computers must be added to the simulation facility.

The interpretation process for a single OBC program instruction requires that the computer load the instruction, isolate and interpret the operation code, and decode the operand address based on the interpretation of the operation code. Then the interpreter must execute one or more instructions to perform the function intended by that OBC instruction. Therefore, the host computer must be several times faster than the OBC which it is simulating. The development cost of such an additional computer with special modifications plus the cost of interface hardware may be prohibitive.

The interpretive simulation technique has been used with considerable success to simulate the Block II AGC and LM guidance computer in CMS and LMS simulators.

#### 6.3.4 Functional Simulation

Developing a functional simulation of an on-board computer requires:

- a) an in depth analysis of the OBC computer hardware and the programs which it executes.
- b) creating mathematical models describing the hardware function and the programs, and their interaction.
- c) programming effort to convert the mathematical models to computer programs in the language of the simulation computer.
- d) testing and verifying these programs, independently and in conjunction with the other simulation programs and with associated control and display hardware.

A functional simulation is characterized by the requirement for simulation data in a well defined form available early in the simulator development program. Data which identifies changes to the OBC programs must also be available a fairly long period of time before these must be available for flight crew training.

Functional simulations of on-board computers have been successfully achieved on a wide range of military and commercial aircraft simulators including the C-130, the F-4 and F-111 series, and the AJ37 military aircraft, the Boeing 707, 747, and the Lockheed L-1011 commercial airliners.

#### 6.4 Tradeoffs and Recommendations

Historically, use of real world hardware in simulators has been characterized as providing a very high fidelity simulation capability. Associated with this fidelity has been a high initial cost. Primarily, the sum of the computer plus interface hardware design, interface material, and the effort for interface software development. If more than one simulator is built, a large percentage of this cost is recurring. The non-recurring costs relate primarily to design of interface equipment and the software development. Since the interface requirements are usually well defined, it can be stated that the technical risk involved in this approach is low. The major risk lies in scheduling to have flight programs available in time for Simulator Test and Crew Training.

The translative approach to DP&S simulation is also applicable to the SMS and its appeal becomes greater as higher level language come into use for OBC programming. Costs of the translative approach to simulation include the required simulation computer hardware (CPU time and memory) plus the non-recurring costs of translator software development. The risk must be considered to be higher than when using real hardware but less than that for the interpretive approach.

As in the real OBC hardware approach, a major constraint to the translative simulation approach is the availability of flight programs. This software must be available in time to test the simulator prior to crew training. Extra care must be taken in the choice of simulation computer to ensure that special anomalies in the OBC are not the source of impossible to solve problems. The simulation computer must be several times as fast as the OBC to allow real time simulation.

The interpretive approach to OBC simulation is also applicable to the SMS OBC simulation. Costs of the interpretive simulation can be attributed to the dedicated computer and interface hardware plus the non-recurring costs of interpreter software and interface software development. If, as appears likely, a special processor is required, additional logistic requirements are also imposed. From an overall simulation viewpoint, it is believed that an interpreter is more difficult to implement than a translator, and is considered to be less efficient in terms of total CPU time and memory required. As for the real hardware approach and the translative approach, the interpreter approach to OBC simulation requires flight programs in time for simulator test and crew training. Again, as for the translative approach,

the computer dedicated to the interpreter must be several times faster and have a larger memory capacity than the OBC which is being simulated

The functional simulation approach is attractive from the viewpoint of total simulation development. Where OBC flight programs are relatively firm, and only minor changes are anticipated, it may prove to be the most cost effective approach. This method requires no special interface hardware, permits a minimum total computation system load, and can be more adaptable to pre-established frequencies of solution. It is the most straight forward to develop and debug, and has the highest probability of real time execution. However, a functional simulation of the on-board computer requires an in depth analysis of the task and a detailed programming effort to model that task in the simulation computer. Full advantage must be taken of the simulation computer programming features to insure a fast and efficient functional simulation. Excessive turn-around time may be required to implement changes to the simulated OBC program when changes to the operational OBC flight program occur.



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As indicated in section 6.1, the Space Shuttle vehicle incorporates a total of 11 digital computers of at least two different types in the Data Processing and Software System and in the Main Engine Controllers.

For each of these systems, a tradeoff study is required to determine the optimum simulation method.

The basis for these tradeoff studies must include such factors as data requirements vs availability and changeability, training requirements and training value, and the impact on total simulation cost, complexity, scheduled delivery, and simulator availability of these factors and other factors such as:

- . Logistic Support Requirements, including Ground Support Equipment and Spare Parts
- . Testing Requirements
- . Maintainability, and Reliability, MTTR, and MTBF

It has been established that the computers to be used in the Data Processing and Software (DP&S) Subsystem of the Shuttle Vehicle will be programmed using a high level language (HAL) and that an additional HAL compiler will also be developed for use with an IBM 360 computer. In addition, the DP&S software, including the assembler, Link Edit and Interpretive Simulation Programs are also required to run on an IBM 360/75 computer.

It can be assumed that a similar compiler can be developed for the Main Simulation Computer with equivalent efficiency in terms of CPU memory and time requirements.

Estimates have been made of the non-recurring and recurring costs of simulation for both the DP&S subsystem and the Main Engine Controller Computers for the four techniques under consideration.

A summary of relative costs is shown in Table 6.4-1. These estimates are relative magnitude and should not be construed exact.

Based on these costs, risks, and the other factors previously mentioned, the number of viable techniques for the DP&S system simulation can now be reduced to two; Real Hardware or Translator/Compiler. The interpretive approach is rejected because cost, risk and development time are considered extremely excessive.

A functional simulation of the DP&S System has been also rejected because of the high costs and high probability that program data will not be available and will change very rapidly.

Currently available NAR schedules for the DP&S subsystem software indicate that flight software will not be available until sometime during the MBCS integration phase. For the DP&S subsystem, a final tradeoff can now be made based on the relative merits of the use of real hardware versus the use of translator/compiler.

For the two crew station complex specified for the SMS, and with relative costs as shown, the real hardware cost is shown to be economically best.

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Since it also involves the least amount of risks, and other factors, are relatively equal, it has been chosen as the recommended simulation approach for the SMS at this time.

For the Main Engine Controller Computers, the programming language will in all likelihood be DAP-16, the assembly language for the Honeywell HDC 601, DDP-516 and Type 716 general purpose computer family. Either translatable approach or the interpretive approach to simulation would require a costly and time consuming software development effort. Therefore, both the translatable and interpretive techniques have been rejected. The real hardware or a functional simulation approach are considered viable. From Table 6.4-1, is also seen that the costs of simulating the Main Engine Controller Computer using non-flight qualified hardware are approximately the same as for the functional simulation. This is because the commercially available Honeywell DDP-516 or Type 716 computer can be used as a direct replacement of the HDC-601 in a simulator application.

TABLE 6.4-1

## OBC SIMULATION RELATIVE COST COMPARISON

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	REAL HARDWARE				TRANSLATOR/COMPILER				INTERPRETER				FUNCTIONAL SIMULATION			
	NON-RECUR	MBCS RECUR	FBCS RECUR	TOTAL	NON-RECUR	MBCS RECUR	FBCS RECUR	TOTAL	NON-RECUR	MBCS RECUR	FBCS RECUR	TOTAL	NON-RECUR	MBCS RECUR	FBCS RECUR	TOTAL
DATA PROCESSING & SOFTWARE SUB-SYSTEM																
ADD-ON CPU HARDWARE		547	682	1229												
PERIPHERALS & TEST EQUIPMENT	294			294												
I/O & INTERFACE HARDWARE		93	123	216												
HARDWARE SYSTEM DESIGN	120			120												
HOST COMPUTER HARDWARE		41	62	103												
HOST COMPUTER SOFTWARE DEV.	20				200	864	1008	1872	200	3120	780	6708	1300	912	1692	1500
OBC DOCUMENTATION	31			31												
I/O & INTERFACE SOFTWARE	40			40												
ASSUMES 3 CPUS IN THE MBCS AND 4 CPUS IN THE FBCS EACH WITH 64K 32 BIT WORD MEMORY (25% SPARE)																
TOTAL	505			2033					2072			6948				3192
MAIN ENGINE CONTROLLER COMPUTER																
ADD-ON CPU HARDWARE		95.6		95.6												
PERIPHERALS & TEST EQUIPMENT	18.6			18.6												
I/O & INTERFACE HARDWARE		10		10												
HARDWARE SYSTEM DESIGN	60			60												
HOST COMPUTER HARDWARE		30		30												
HOST COMPUTER SOFTWARE	20			20	200											240
ASSUME 3 CPUS WITH 32K 16 BIT MEMORY (50% SPARE)																
TOTAL				234.2					N/A				N/A			240

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The DDP-516 or Type 716 commercial processors are compatible in programming software and I/O interface with the HDC-601. As a result of software compatibility, a complete field tested library, including application and utility programs is currently available. In addition, an assembler and a Fortran IV compiler are available to assist new program preparations.

All DDP-516 product line peripherals may be interconnected with the HDC-601. These peripherals include teletype equipment, high speed printers, CRT displays, high speed paper tape equipment, punched card equipment, disc files, magnetic tapes and communications modems.

New data inputs, and further evaluation of the simulation requirements over the next several months, may reveal the one approach or the other to the Main Engine Controller Computer simulation is preferred. It is therefore recommended that the final choice of simulation technique for the Main Engine Controller be deferred until more data is available. Additional data is also required for DP&S subsystem, which will also have impact on the SMS. As an example, the costs of the DP&S hardware may decrease or increase, based on such factors as:

a) The programs in the primary and backup GN&C computers might be the same - hence it might be possible to eliminate one or more DP&S computer, or

b) The second auxiliary computer is operational in parallel with the first, and contains different programs, or

c) A HAL compiler is already available for the main simulation computer, or

d) Considered from the higher level of total OBC simulation requirements, the attributes of the Honeywell minicomputer family also may lend themselves to an additional application which might prove cost effective and attractive from a logistic point of view. The Type 716 computer used to perform the Main Engine Controller computer simulation function is sufficiently powerful to provide the interface controller operation for the DP&S System.

**Based on data available at this time, one approach to the total OBC simulation, using real hardware, has been conceived.**

Figure 6.4-1 is a block diagram of this approach. For evaluation purposes, certain basic assumptions have been made relative to the DP&S system operation and to simulation requirements. These assumptions are as follows:

a) The operation of the primary GN&C computers is such that **only one of the two** primary GN&C computers is operating at one **time**. The other Primary GN&C computer is assumed to be in a standby mode and providing no outputs to any avionics system.

REFERENCES:		ENGINEER		REV.	TITLE		REP. NO.		PAGE NO.		OF
THE SINGER COMPANY SIMULATION PRODUCTS DIVISION BINGHAMTON, NEW YORK					SIMULATOR						
NAME		DATE									

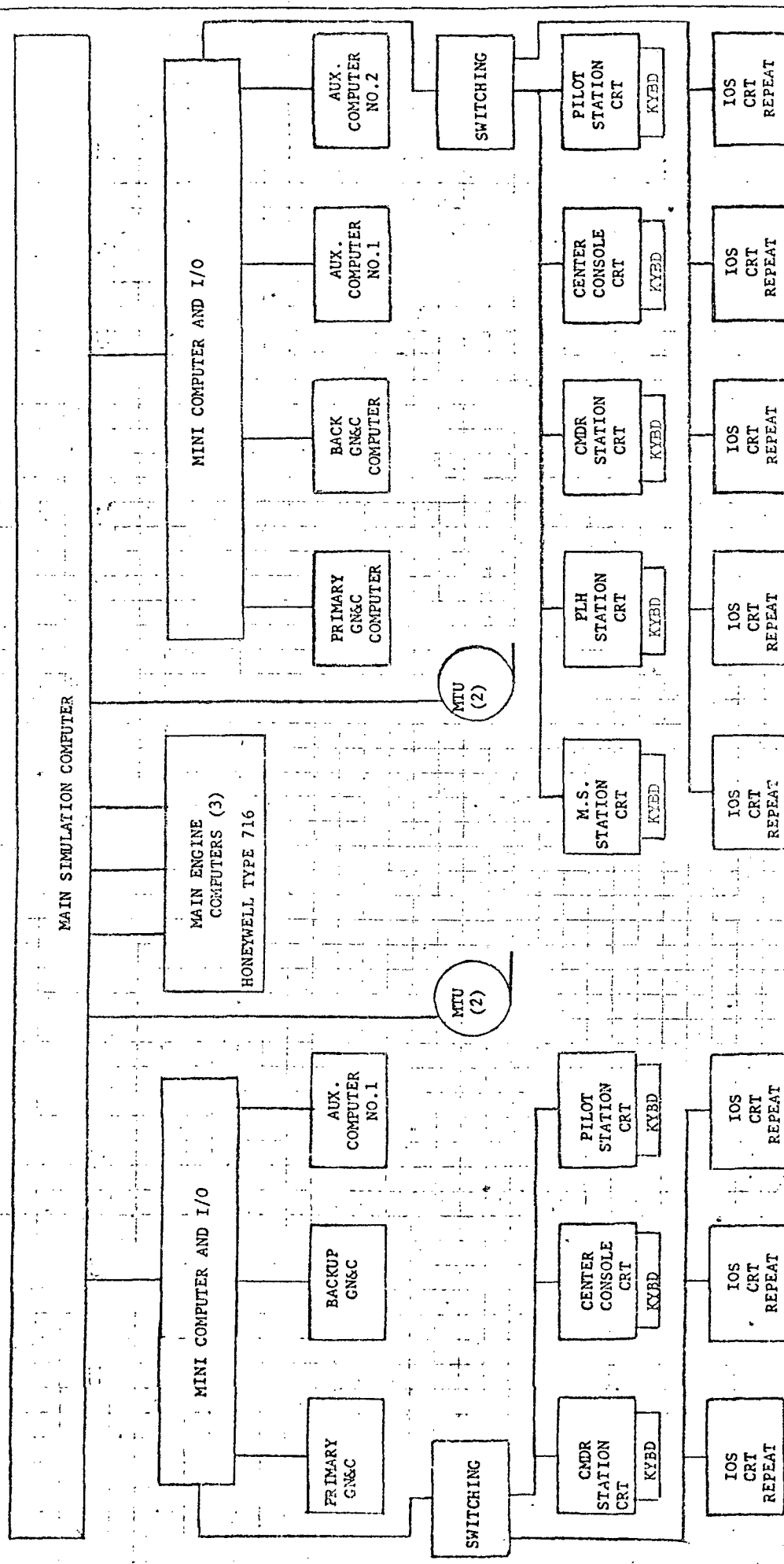


FIGURE 6.4-1

OBC SIMULATION BLOCK DIAGRAM

MOTION BASE CREW STATION

FIXED BASE CREW STATION

b) The simulation of the Launch-Boost phase will not be required simultaneously in both the MBCS and the FBCS.

c) The three Main Engine Controller Computer programs may be time-shared between the Motion Base Simulator and the Fixed Base Simulator by appropriate switching and multiplexing of data in the Main Simulation computer.

Payload handling simulation is not required in the motion base crew station simulator. Therefore, the second auxiliary DP&S computer will not be required.

The motion base crew station on-board computer simulation will include three of the DP&S computers plus the three Main Engine Controller computers. The three DP&S computers will be one of the Primary GN&C, the Backup GN&C, and one of the Auxiliary computers for Performance Monitoring.

CRT Displays and Keyboards for the Commander and Pilot will be provided with associated IOS CRT Repeaters. These CRT Displays and Keyboards will be provided GFE.

The two Magnetic Tape units will also be provided (GFE) for program reload operations.

The Fixed Base Crew Station OBC simulation will incorporate an additional four DP&S computers; one primary GN&C, one Backup GN&C, and the two Auxiliary computers.

The Main Engine computers provided in the MBCS will be shared by the FBCS. The additional (GFE) CRT Displays and Keyboards for all crew positions will be provided, with repeater CRT's for the IOS. Two additional Magnetic Tape Units will also be provided for the FBCS.



## 7.0 Data Conversion Equipment

### 7.1 General

Data Conversion Equipment (DCE) is defined as equipment required for conversion and formatting of analog and digital signals input to and output from the digital computation system to/from the remaining portions of the SMS. In this context, it includes the main host computer interface equipment plus Analog/Digital, Digital/Analog, Discrete Digital Signal Input, and Discrete Digital Signal Output conversion equipment and specialized conversion hardware such as Electronic Synchro Resolver Drivers.

The DCE requirements for both the MBCS and for the FBCS simulators are summarized in Table 7.1-1. It can be seen that these requirements are very large - comparable to more than two large aircraft simulators.

### 7.2 Computer - DCE Interface

The available techniques for achieving a satisfactory computer interface with a large Digital Conversion System are limited. To a very great extent, the actual hardware interface is dependent on the design of the computer and its interface options. Most DCE system designs are tailored to satisfy the requirements of the particular computer chosen. Because of the simulation requirement to transfer large numbers of digital words per unit time, both into and out of CPU core memory, the established practical norm has become a Bit Parallel, Word Serial Format.

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	<u>Analog Input</u>	<u>Analog Output</u>	<u>Discrete Input</u>	<u>Discrete Output</u>
Motion Base Crew Station				
Crew Station	34	156	1765	1436
Instructor/Operator Station	1	98	119	303
Motion	7	8	1	2
Visual	104	302	8	1
Aural Cue		70		
Voice Communications		6		67
Sub Total	146	640	1893	1809
Fixed Base Crew Station				
Crew Station	37	177	2192	1737
Instructor/Operator Station	1	117	140	417
Visual	-	50	48	1328
Aural Cue		70		
Voice Communications		6		67
Sub Total	38	420	2380	3549
Total SMS	184	1060	4273	5358
Spare at 25%	46	265	1068	1339
Total Required	230	1325	5341	6697

Table 7.1-1  
SMS DCE REQUIREMENTS

c. When the Device Controller word counter reaches zero it flags the CPU I/O Controller (via an interrupt) that it has completed its operation and is ready for the next command.

Virtually all simulation DCE is designed to operate in this Basic Mode. The only known exception being very small systems (under 100 digital words) which operate directly from the computer I/O Bus under program control for each input or output word transfer.

With large quantities of data required to be transferred and the update rates also required to maintain faithful "Real Time" simulation, this technique is also preferred because it enables the block transfer to take place on a "cycle stealing" basis without tying up the CPU for each word transfer. The chief characteristic of the DMA Transfer technique is its inherent high speed and the fact it allows the host CPU and the I/O Controller to be used at maximum efficiency for I/O transfers.

The data transfer rate of a typical DCE system, exclusive of computer overhead, is one data word exchange every two micro-seconds. Assuming a twenty iteration per second I/O rate, and using the total DCE provision as identified in Table 7.1-1, I/O time requirements can be calculated as follows:

CASE I - Assume that DI unpacking and DO packing occurs in the DCE hardware and that DI and DO data are resident in computer memory at one bit per byte. Data transfers are by 16-bit word.

Techniques which have been considered for accomplishing the SMS DCE Interface are:

- 1) The Direct Memory Access (DMA) from the Main Simulator CPU using data block transfers under real time I/O program control.
- 2) DCE Service Interrupt Interface
- 3) DCE Interface via a separate satellite computer or I/O controller, utilizing DMA data block transfers.

It is pertinent to note that in the SMS the total software requirement consisting of the real time simulation programs plus remote batch and interactive terminal processing, is so very large that only an extremely powerful computer complex can completely satisfy the requirement. Computers of this class sometimes include special I/O processors which are in reality mini computers of a specialized design.

Because the main simulation computer recommended for the SMS may not include such a processor, it is recommended that the SMS DCE interface be accomplished using DMA transfers from a satellite mini computer attached to the main computer. This technique offers additional benefits in reducing the load on the main simulation computer to perform tasks of data formatting, and fixed-point/floating point conversions.

The technique is discussed in more detail in the following paragraphs.

### 7.2.1 DMA, Data Block Transfers Under Real Time I/O Program Control

This technique permits data transfer via direct memory access from an I/O controller in the main computer or by use of a separate Satellite processor. The I/O Program controls device type (D/A, A/D, DI, DO) selected, and basic update rate. A DMA controller contains registers used to:

- a. Store the word count for each block transfer
- b. Store DCE status and commands
- c. Store input and/or output data

The I/O Program then commands a particular transfer operation of X words (or Bytes) to or from a specified starting core location, for a particular DCE device type. The command is implemented as follows:

- a. The number of words to be transferred are stored in the Word counter of the DMA Device Controller.
- b. The DMA Device Controller, independent of the CPU I/O Controller but in a priority, cycle stealing architecture, then commences the sequential word transfer to or from the starting core location and decrements its word counter until the block transfer is completed. Each transfer is carried out via a hand shaking operation between the Device Controller and the DCE System Controller. This assures the necessary control and synchronization between the two devices, which generally have completely independent clocks.

$$t_{AI} = 20 \times 230 \times 2 = 9,200$$

$$t_{AO} = 20 \times 1283 \times 2 = 51,320$$

$$t_{DI} = 20 \times 5120 \times 2/2 = 102,400$$

$$t_{DO} = 20 \times 6560 \times 2/2 = \underline{131,200}$$

294,120 Microseconds per second

CASE II - Assume no packing or unpacking of DI and DO words by external hardware. Therefore DI words must be unpacked by a computer program, and DO words must be packed. This reduces the amount of external hardware in the DCE but with a subsequent increase in computer load. Assume DI and DO are packed 16 bits per word.

$$t_{AI} = 20 \times 230 \times 2 = 3,840$$

$$t_{AO} = 20 \times 1283 \times 2 = 35,840$$

$$t_{DI} = 20 \times 5120/16 = 6,400$$

$$t_{DO} = 20 \times 6560/16 = \underline{8,200}$$

54,280

However this case requires a computer program to pack DI and unpack DO, and additional memory to store the data.

For the case under consideration the additional data memory is approximately 130 words. A computer program to unpack all 320 packed DI words and pack 410 DO words is estimated to require approximately 14,000 microseconds per iteration.

At 20 iterations per second this amounts to approximately 28 percent of the available minicomputer time.

Hence a tradeoff can be made related to use of dedicated hardware or the use of a minicomputer program to pack and unpack Discrete I/O variables.

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The costs of this dedicated hardware have been found to be very small. Therefore this approach is recommended for the S.M.S. The DCE minicomputer will be utilized for analog I/O data scaling, fixed-floating conversions and for control and formatting of the Telemetry data transmission to M.C.C.

It is recommended that computer interfacing of the SMS DCE equipment be accomplished utilizing two separate multiplexed DMA device controller channels, one for the Motion Base Crew Station and one for the Fixed Base Crew Station. This scheme effectively splits the data and time loading as opposed to using only one DMA channel for the entire DCE system. It permits a higher average through-put rate and is considered adequate in light of the cost and risk of developing more exotic techniques. It also effectively divides the DCE into two deliverable entities, one for the MBCS and one for the FBCS.

### 7.3 DCE Configurations

#### 7.3.1 General

At the present time nearly all simulation applications utilize a centralized DCE system of one form or another. Until recently, it has been impractical to segment sections of DCE equipment due to physical size and weight limitations of equipment packaging especially where these electronic assemblies have an adverse effect on the usable payload capabilities of motion systems. The centralized DCE system has utilized the highest packaging efficiency practical. This is due primarily to the following:

1. DCE has been supplied by Computer Manufacturers who, having had no specific knowledge of the simulator application, have packaged their equipment in their classical manner and in a highly modular form.

2. Where simulator manufacturers have designed their own systems, the modular approach has been adhered to principally to minimize costs for large numbers of like devices.

With the rapidly expanding availability of specialized LSI and MSI circuitry and analog to digital and digital to analog converter modules, a great wealth of "Bits and Pieces" hardware exists for structuring DCE systems. It is true, however, that the user has been left largely to his own initiative to design, configure and build systems from this hardware. Therefore, Distributed DCE systems have existed mainly as special purpose configurations in particular applications.



In the area of simulation, Distributed DCE has been mainly the result of the simulator manufacturer's efforts to improve performance and reduce system costs while still maintaining some degree of flexibility. Therefore, the simulator complex configuration has dictated the degree of modularity since a simulator is made up of physically separable section as indicated in Table 7.1-1.

I/O Device types and quantities attributable to each section change radically in going from one type aircraft or spacecraft to another. Also, the I/O Device types and quantities are a function of the Basic Motion and Visual systems anticipated to be used.

### 7.3.2 Centralized DCE

In the broadest sense, the technique of centralized DCE is based primarily on a packaging scheme and only indirectly results in the addition or omission of electronic hardware because of the packaging methodology. A centralized DCE system consists of all the necessary electronic hardware (A/D's, D/A's, DI's, DO's, control and steering logic, etc.) housed in one or more equipment cabinets in close proximity to each other and generally also in close proximity to the simulator's computer complex.

Other characteristics of the centralized DCE are as follows:

1. Requires a comparatively simple and efficient method of obtaining and distributing DC power.
2. Permits single point maintenance for all sections of the DCE.

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3. Avoids the necessity of hardware and driver/receiver electronics to distribute high-frequency Digital Data and Control signals around the simulator complex over long lines and also avoids the use of electronic logic required to multiplex and demultiplex the data transferred in bit parallel, word serial format.

4. Simplifies the addition of such optional DCE features as closed-loop self-test since all the DCE Equipment inputs and outputs are centrally located for ease of accessibility.

5. Location in close proximity to the computer complex minimizes the payload required to be carried on the Motion System for DCE related to devices in the trainer areas.

6. Requires the least amount of packaging designs and hardware variations.

7. Requires long cable runs to the trainer electronics assemblies with consequent analog noise susceptibility problem considerations.

8. Requires several cabinets worth of floor space in the trainer floor plan.

There are almost continuous opportunities to reduce the total volume and cost of any given DCE System with the development of new LSI/MSI Electronics and related packaging schemes. The limiting element here, however, is the efficiency with which I/O Signal cabling and cable distribution can be integrated into electronic packaging designs.

Presently, the cost of small modular D/A converters has been reduced to the level where it is economically feasible to design and build a DCE analog output subsystem having a dedicated converter and buffer register for each channel.

Virtually all simulation DCE equipment produced to date tends toward the centralized DCE technique. A minor variation to this is the placement of some particular quantity of DCE hardware located physically closer to the using devices. (This technique is used on some of Singer Co.'s large commercial simulators, namely, the 747's and L-1011's where some DI and DO P/C card gates are located in the cockpit atop the 60-inch stroke, synergistic motion system.

More recently, Singer-SPD has developed and produced a Centralized DCE System being used on its current 727 and C-130 Simulators known as the "T-Linkage". A significant cost reduction was realized along with reduction in system volume through the use of wire-wrapped, DIP Socket back plane gates for the entire digital and control portion of the DCE system, thus eliminating all printed circuit cards from that section. Logistical support problems were consequently reduced since the most probable item requiring replacement has now become the IC itself. A block diagram of the system is shown in Figure 8.3-1.

The system can be configured as follows:

- a. DI: Modules of 8 16-bit words expandable to a total of 224 words.

(May be TTL or 28 V DI's chosen in Blocks of 8 words.)

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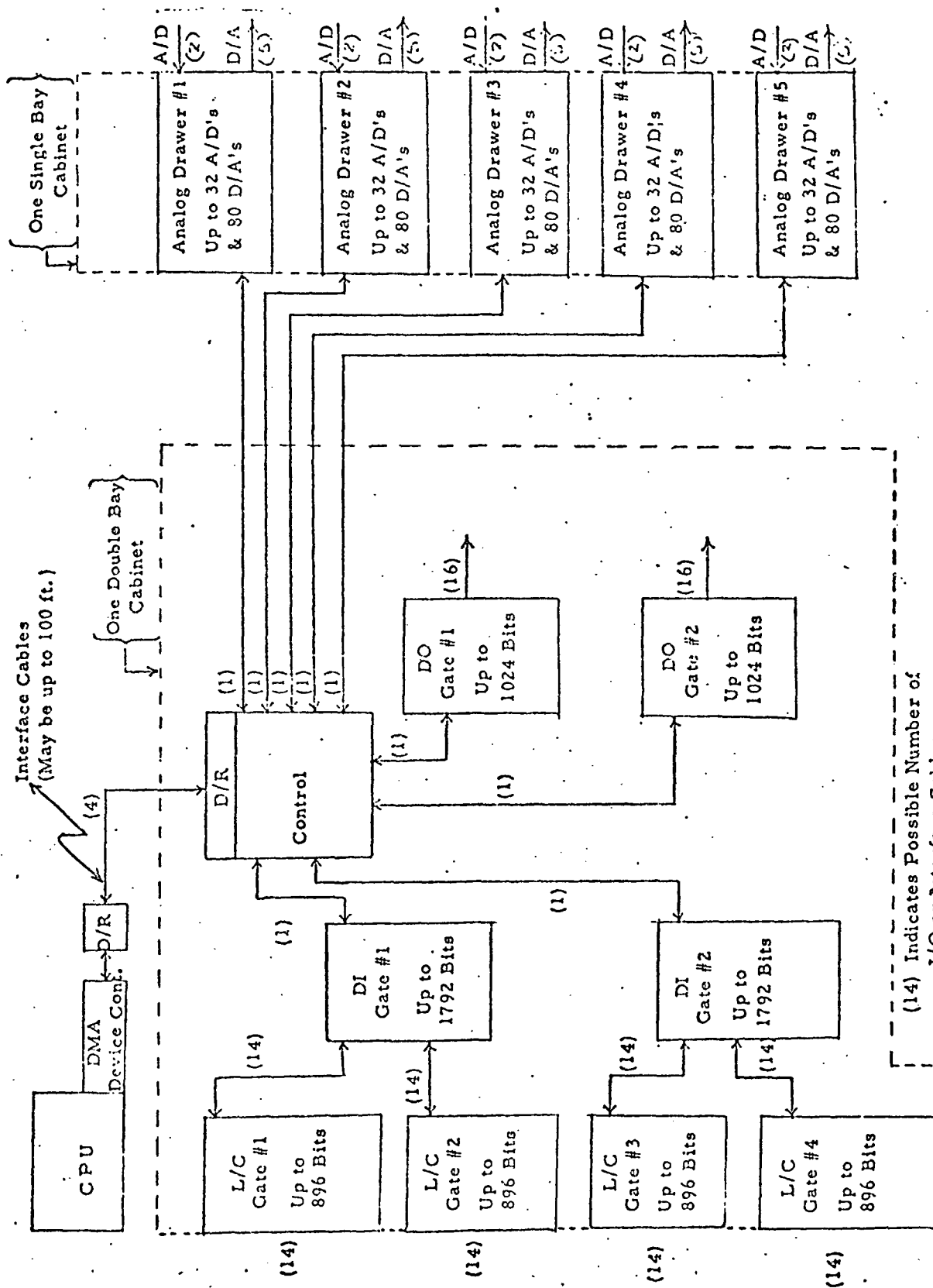
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Figure 7.3.2-1 SPD "T" LINKAGE

Gate Dimensions are nominally 19" x 34" x 4"

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b. DO: Modules of 8 16-bit words expandable to a total of 128 words.

(May be TTL or Lamp Driver DO's chosen in blocks of 8 words.)

c. A/D: Modules of 16 channels expandable to a system total of 192 channels. ( $\pm 10V$  range, 10 bits + sign)

The A/D subsystem utilizes one ADC and 4 8-channels multiplexers for each 32 channels and has low pass filters with a 50 Hz cutoff on each channel.

d. D/A: Modules of 16 channels expandable to a system total of 400 channels. ( $\pm 10V$  range, 10 bits + Sign.)

The analog subsystem is made up of drawers and P/C cards, each drawer having the capability of 32 A/D's and 80 D/A's. The D/A subsystem utilizes a sample/hold technique, with two DAC's utilized for each 80 channels and either 7 Hz or 320 Hz low pass filters on each channel. Filtering selection is applicable to 16-channel blocks.

The Main DCE Controller is configured for full system expansion.

Other features of the system include:

a. High speed, dual differential line driver/receiver system, allowing the DCE system to be up to 100 feet away from the CPU I/O DMA Device Controller.

b. DO & D/A Update fail indication and override (used to interlock simulator DC power and main simulator status).

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c. Hardware DI & DO Bit Processor for packing and unpacking Boolean Bits of DI & DO.

d. Starting channel address and range feature.

e. Analog, subsystem also provides  $\pm 10$  volt reference voltage for simulator A/D signal generation hardware.

f. High speed digital conversion equipment -  $32 \mu\text{sec}$  average A/D conversion time.  $64 \mu\text{sec}$  average D/A conversion time. Digital Input & Output transfers at the rate of  $1 \mu\text{sec}$  per word transfer (exclusive of Computer Overhead).

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### 7.3.3 Distributed DCE

The technique of Distributed DCE is again based primarily on a packaging scheme, and only indirectly results in the addition or omission of electronics hardware because of a particular packaging and Distribution Methodology. The Basic Distributed DCE System still consists of the necessary electronics hardware (A/D's, D/A's, DO's, Control and steering logic, etc.). However, based on a particular desired configuration, additional multiplexing and demultiplexing electronics and control logic is required for data steering for each "black box" module of DCE equipment around the simulator complex. There are a number of Design philosophies which can be considered in the design of a Distributed DCE System.

1. A central controller and a number of DCE subpackages where each subpackage has the capability of housing all DCE Device Types (D/A, A/D, DI, DO) in various quantities. See Figure 7.3.3-1
2. A central controller and a number of DCE subpackages where each subpackage has the capability of housing a variable quantity of only one Device Type. See Figure 7.3.3-2.
3. A direct interface to the computer with a controller for each Device type plus a number of DCE subpackages where each subpackage has the capability of housing a variable quantity of the particular Devices. See Figure 7.3.3-3.
4. Figure 7.3.3-4 partially illustrates that, without regard to

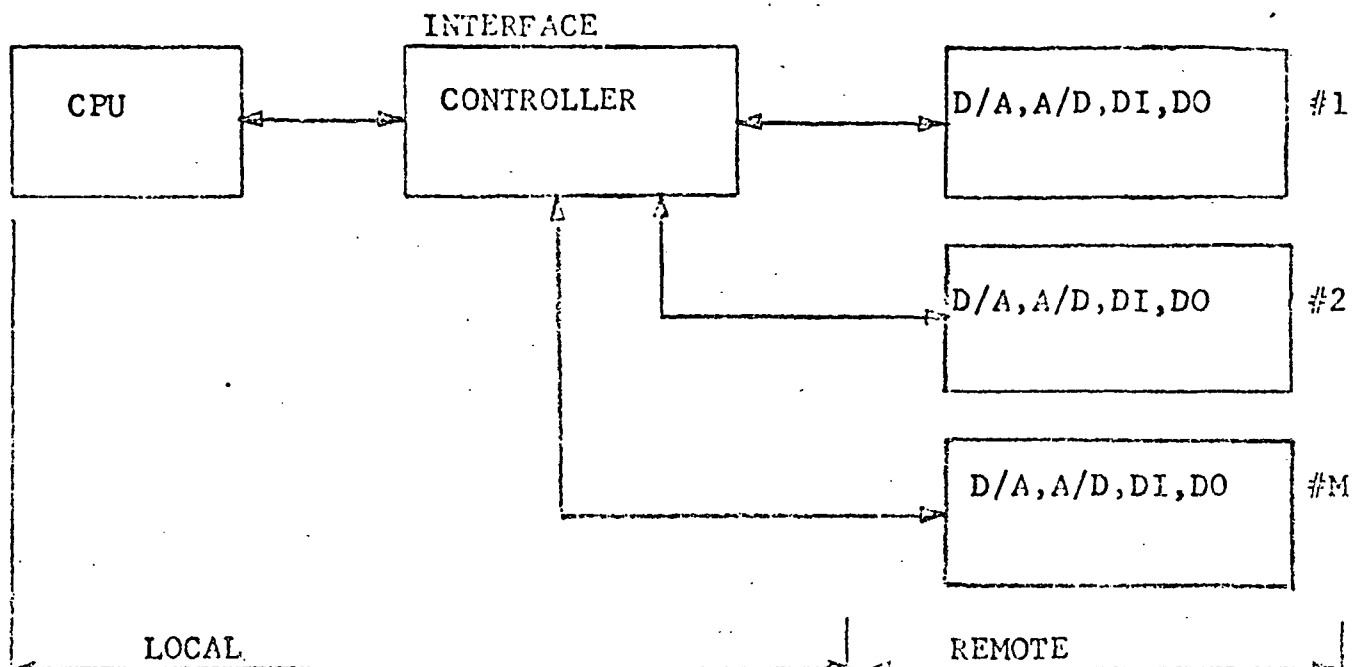
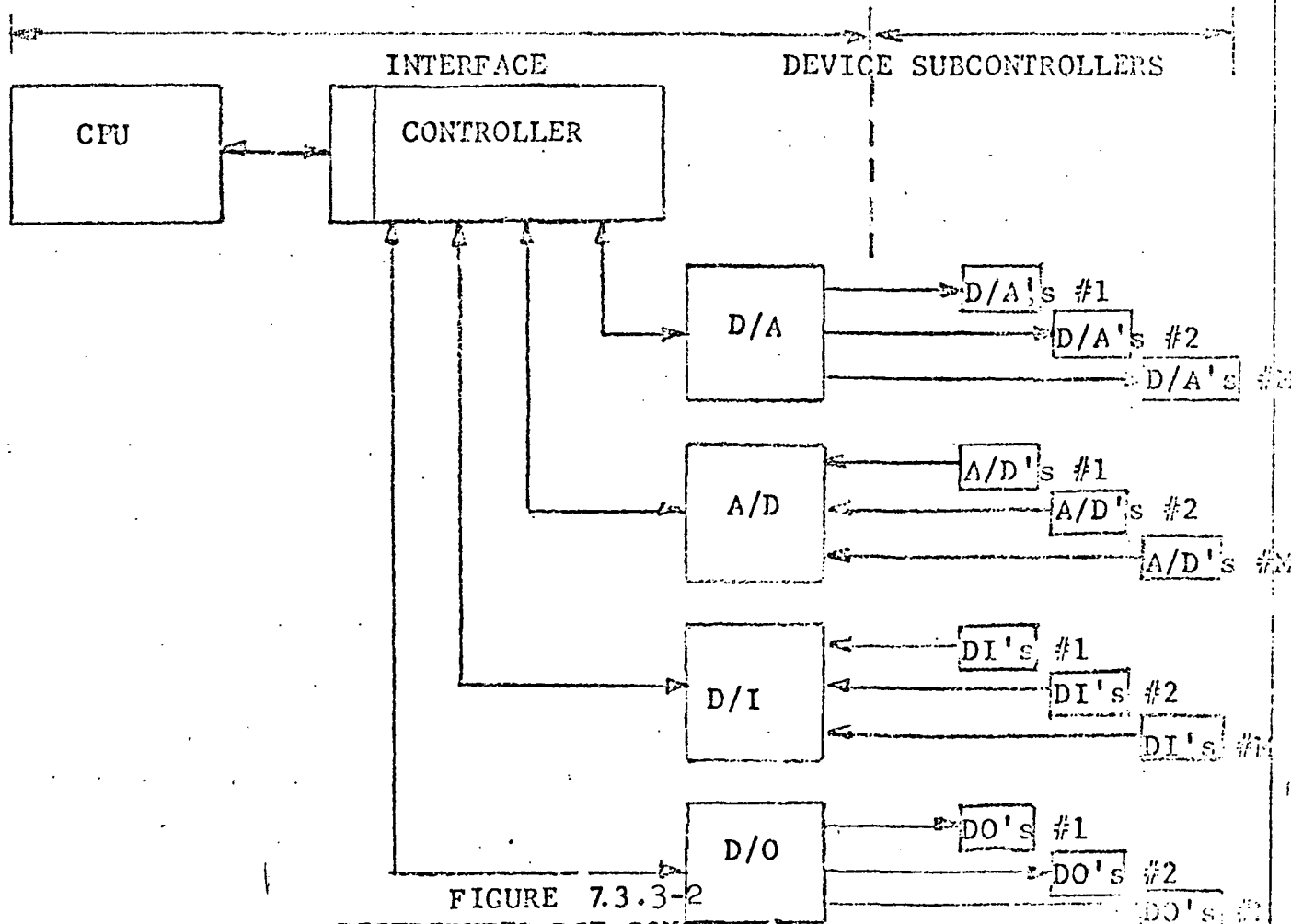


FIGURE 7.3.3-1 DISTRIBUTED DCE CONCEPT A.

FIGURE 7.3.3-2  
DISTRIBUTED DCE CONCEPT B



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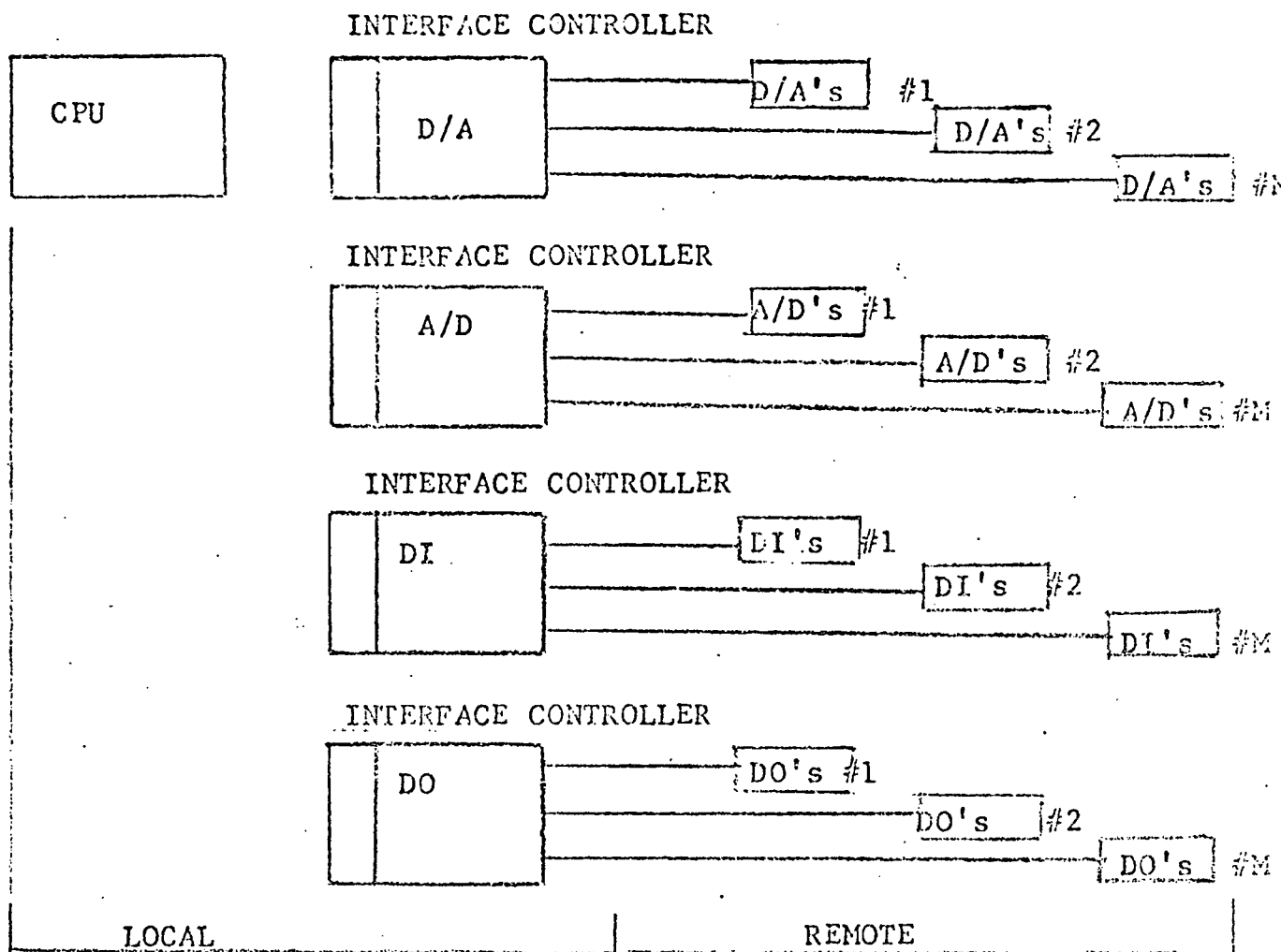


FIGURE 7.3.3-3 DISTRIBUTED DCE CONCEPT C

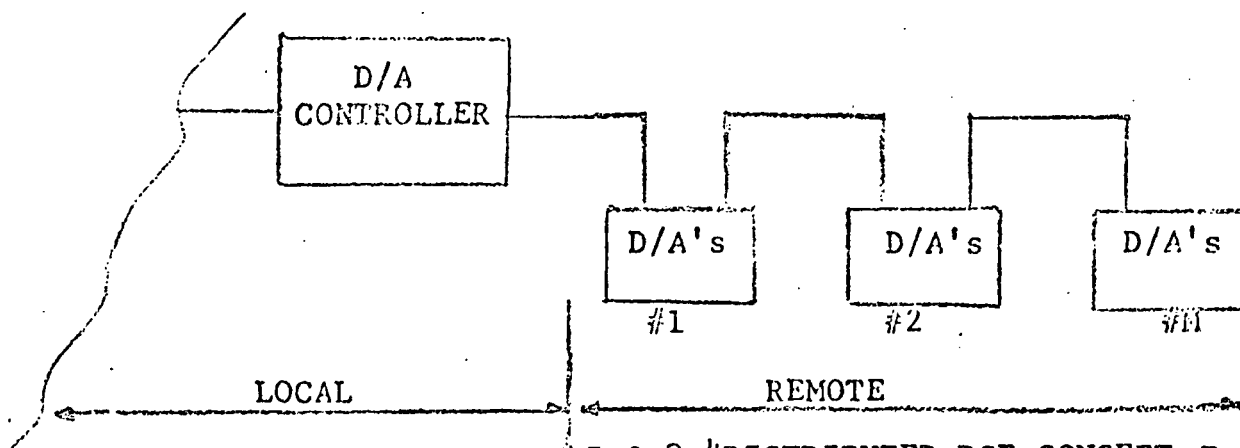


FIGURE 7.3.3-4 DISTRIBUTED DCE CONCEPT D

interface/control configuration, how the Remote Functional Devices can be daisy chain connected with respect to the Distribution/Collection of Digital Data.

Additional characteristics of a Distributed DCE System are as follows:

1. Update rates and effective data throughput are constrained by the specific interface and control techniques and by the total data path length around the simulator complex.
2. The number of combinations of configurations is practically unlimited.
3. By attention to proper hardware and software design considerations, it is possible to design a system which is directly DCE channel addressable through the use of control words in the I/O Programs (starting channel address and range).
4. In large systems, it can significantly reduce the complexity and bulk of long, signal distribution cables. This can be an important weight and cost factor especially with regard to a large, complex, simulator cockpit/trainee station atop a motion system.
5. By placing the analog conversion devices close to their sources and loads, the overall noise susceptibility of the analog systems can be reduced. Therefore, high resolution and accuracy conversion devices can then be utilized to their fullest potential in the system design sense.

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6. Eliminates need for special interface cabinets.
7. Overall simulator costs (recurring plus non-recurring) may be minimized for one or two unique products.
8. Additional digital transmission electronics, connectors, and more exotic cable types are required.
9. Imposes space and weight penalties in the trainee area.
10. Based on system design and modularity considerations may require a more complex device subaddressing scheme.
11. Where DCE self test or calibration features must be made an integral part of the DCE system, the self test design may become unwieldy and more expensive than in a centralized DCE system.
12. It becomes more difficult at initial design to adequately address the problem of spare channel provisioning for potential growth of the simulator.
13. Design effort and risk increase due to the necessity of evaluating and making provisions for data and control propagation delays through the overall system.

As an example of a Distributed DCE system, the Singer Silver Springs Operation (SSO) Division has recently developed a system for application to a Nuclear Reactor Simulator. The main purpose for this development was to reduce the cabling, connector, and component count, and to provide a system less susceptible to EMI/RFI noise.

To accomplish this, a method to communicate with a high speed computer and the simulated systems over a very small number of wires was conceived. The system is shown in a comparative sense in Figure 8.3- Note the distance between the computer area and the using systems is traversed by only a few wires in the distributed system and several thousand in the centralized system. Figure 8.3-7 shows an application of the distributed I/O system to the nuclear power station simulator. The two busses (25 twisted pair) replace the sixty cables (100 wires each cable) of the conventional or centralized system.

The distributed I/O system is comprised of the following units:

- a. I/O Master Controller
- b. I/O Subcontroller
- c. DI Unit (discrete input)
- d. DO Unit (discrete output)
- e. RO/LO Unit (relay/lamp driver output)

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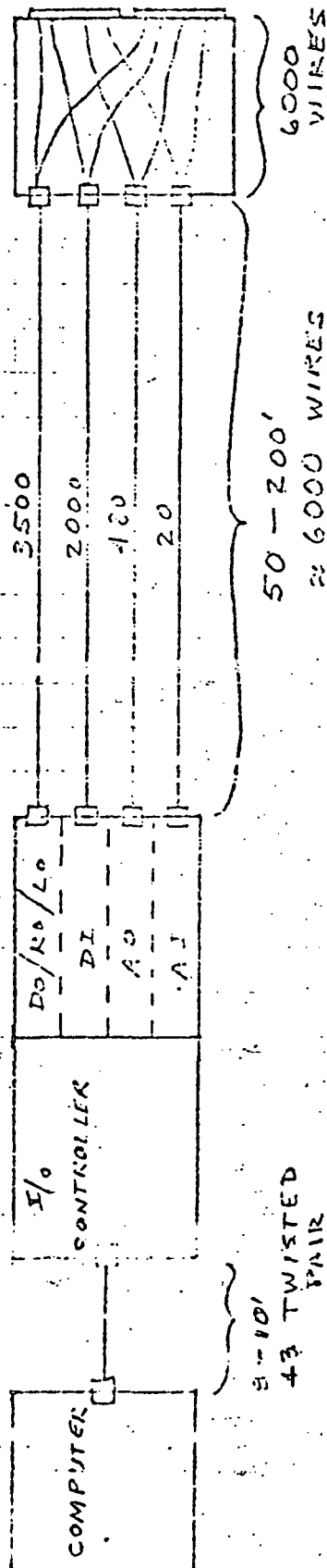
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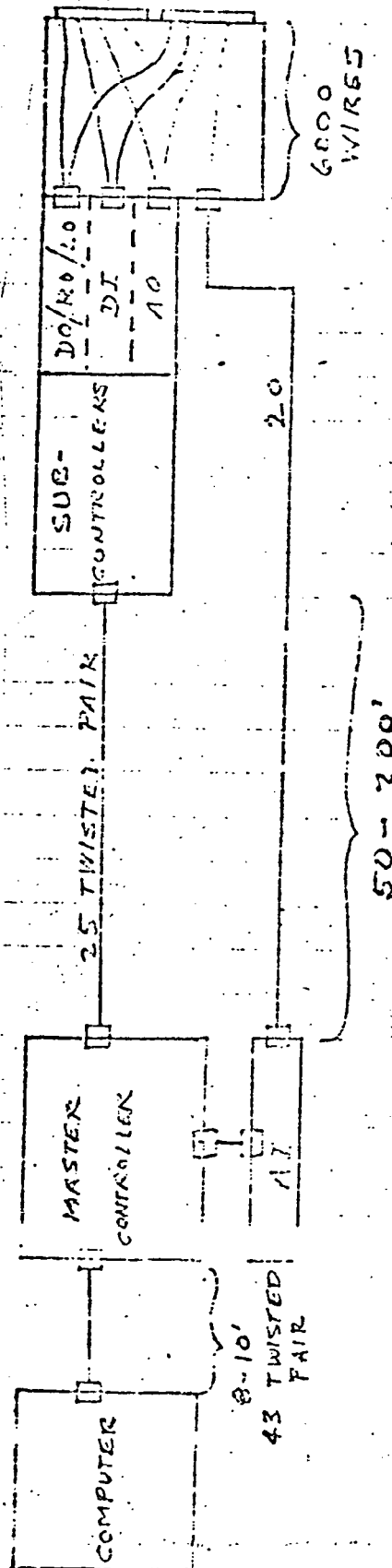
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CENTRALIZED



SAVINGS

- 60 CABLES - 100 WIRES
- 320,000 FEET WIRE
- 120 CONNECTORS

DISTRIBUTED

Figure 7.3.3-5  
Comparison of Central vs. Distributed Interface

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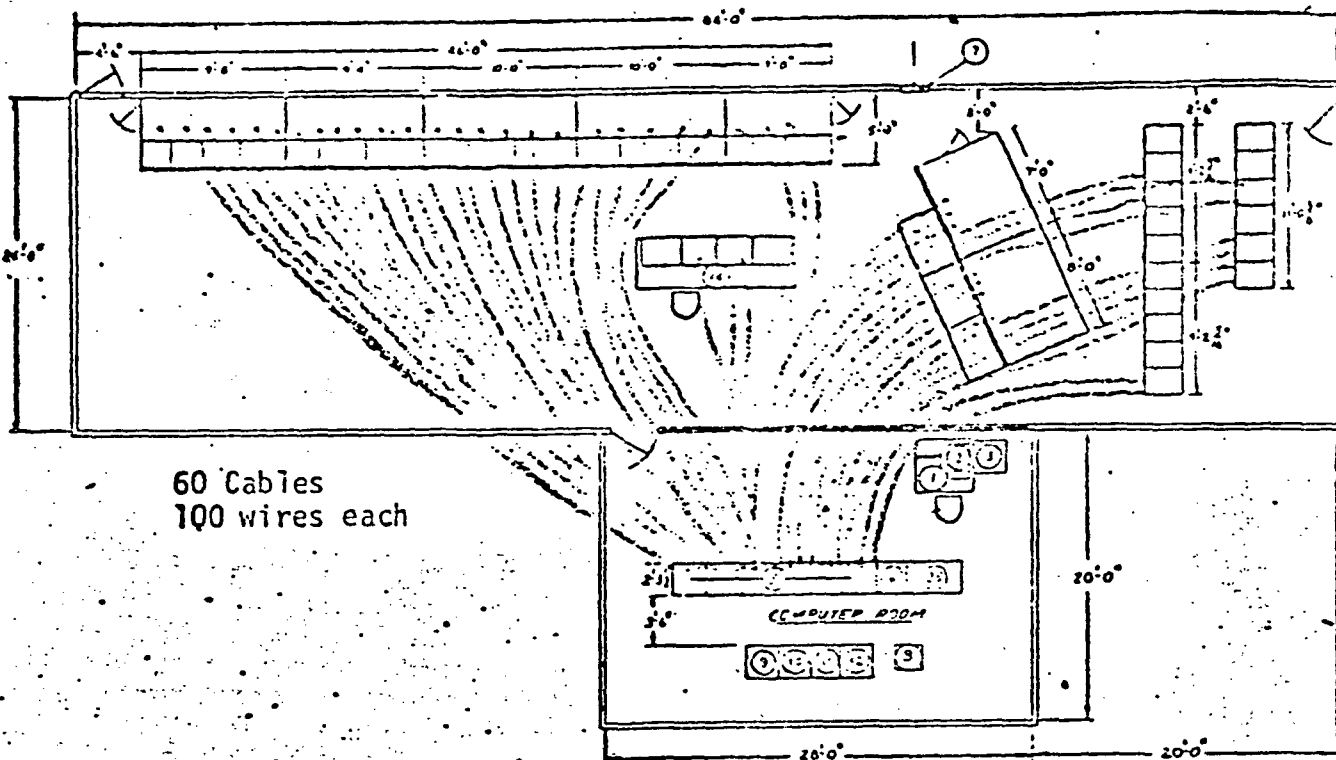
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CENTRALIZED INTERFACE SYSTEM

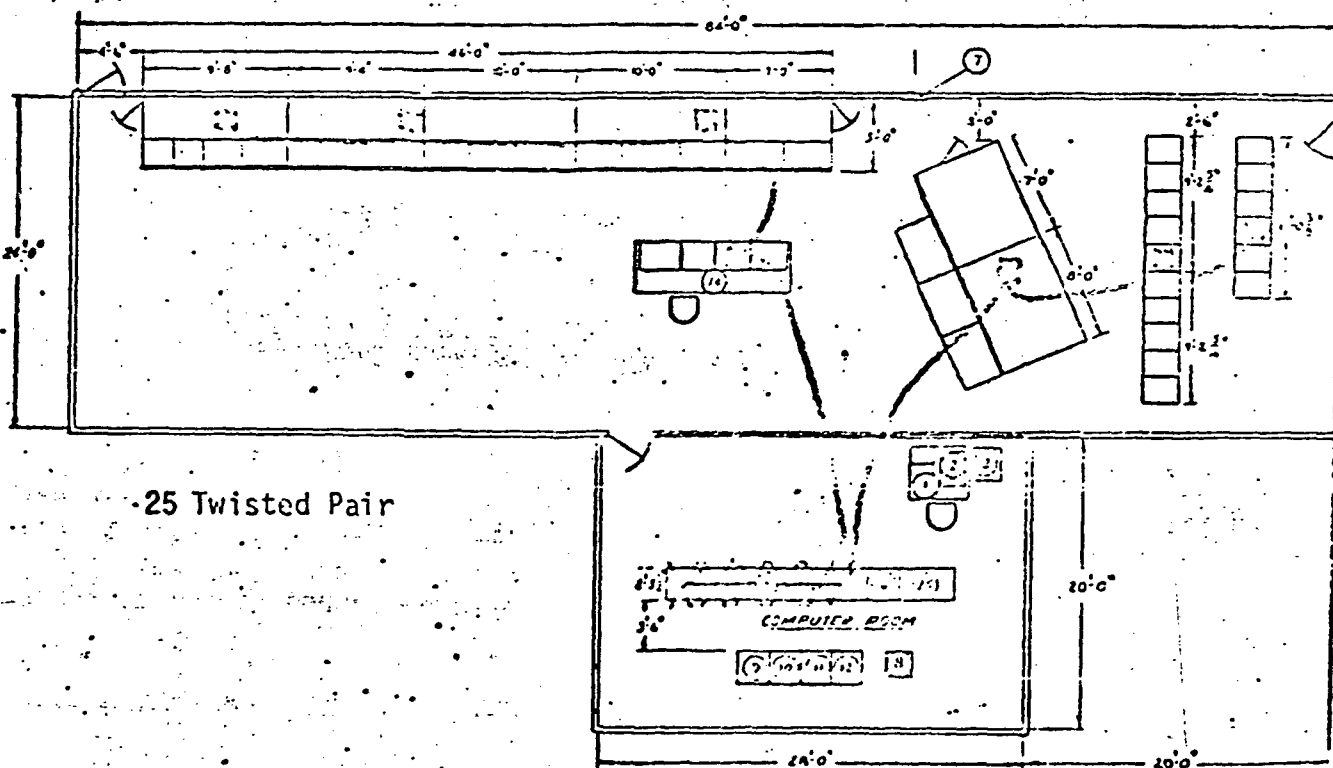


Figure 7.3.3-6 DISTRIBUTED INTERFACE SYSTEM  
Central vs. Distributed Interface for Typical Nuclear Simulator

f. AO Unit (analog output)

g. A/D Converter (analog input)

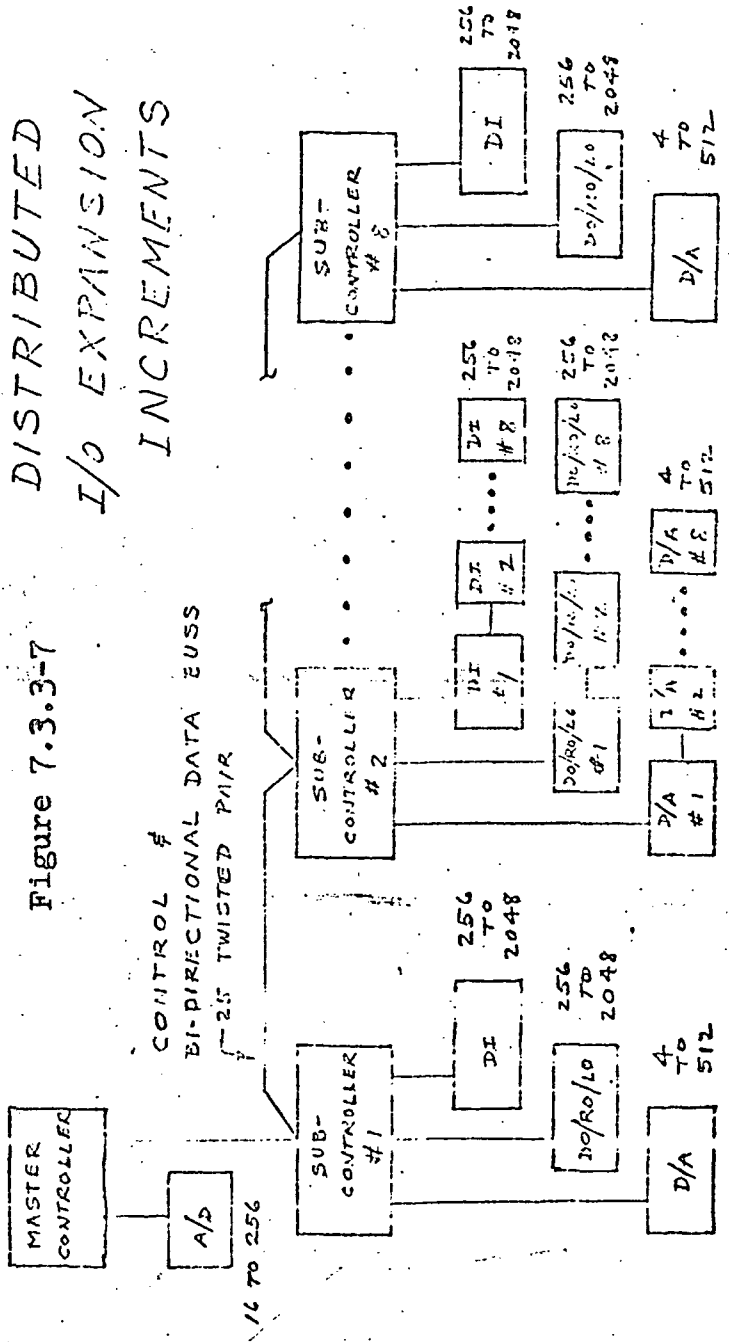
These units are off-the-shelf and may be configured in many different combinations. Figure 8.3-8 shows the expansion capabilities of the distributed I/O system. The I/O master controller is presently configured to operate from a PDP 11 high speed (DMA) channel but can readily be configured to most computers. The master controller can handle up to eight subcontrollers. The subcontrollers can handle up to eight discrete input-units, eight analog output units and eight digital output units. The digital output units can be any combination of discrete output and/or relay-lamp driver output type units. The subcontrollers are all wired identically as are the different types of input-output units.

#### I/O Master Controller

The I/O Master Controller contains the circuitry to perform computer handshake, mode control, master addressing, data distribution, bus control, interface timing, and real time clock functions. The I/O Master Controller is housed in a single row planar frame, which is mounted in the Simulation Computer. The I/O Master Controller drives a control and bidirectional data bus which can handle up to eight subcontrollers. The bus is a single cable of 25 twisted pairs. All the 25 twisted pair (between the master controller and the subcontrollers), including the bidirectional data bus, use differential line drivers and

# DISTRIBUTED I/O EXPANSION INCREMENTS

Figure 7.3.3-7





receivers for added drive capability, pulse shaping, and noise immunity.

#### I/O Subcontroller

The I/O Subcontroller contains the circuitry to perform I/O unit addressing, mode decoding, and bidirectional data driving functions.

Each subcontroller is housed in a single row planar frame, which would mount on standard 19" RETMA rails close to the simulated equipment. Each subcontroller can address up to eight DI units, eight DO or RO/LO units and eight AO units. The I/O units are connected to the subcontrollers with pin-to-pin jumper cables as the bidirectional data bus.

#### DI Unit (Discrete Input)

The DI unit contains the circuitry for multiplexing up to 16 words of discrete inputs (256 bits). The hardware is housed in a single row planar frame which mounts on standard 19" RETMA rails. DI's are connected to the DI unit through 50 pin connectors (3 words per connector).

#### DO Unit (Discrete Output)

The DO unit contains the circuitry for storing and driving 16 words (256 bits) of TTL compatible outputs. The hardware is housed in a single row planar frame which mounts on standard 19" RETMA rails. DO's are connected to the DO unit through 50 pin connectors (3 words per connector).

### RO/LO Unit (Relay/Lamp Driver Output)

The RO/LO unit contains the circuits for storing and supplying ground sink for driving 16 words (256 bits) of Relay/Lamp outputs. The hardware is housed in a two row planar frame which mounts on standard 19" RETMA rails. RO/LO's are connected to the RO/LO unit through 50 pin connectors (3 words per connector).

### AO Unit (Analog Output)

The AO unit consists of a printed circuit motherboard which holds up to 16 four channel D/A cards (64 channels per unit). This unit mounts on standard 19" RETMA rails. Preliminary investigations indicate that present LSI technology may permit even further breakthroughs in the D/A design. This investigation is continuing and any later design will be incorporated in the Applications Reports as appropriate.

### AI Unit (Analog Input)

The analog input unit is an analog to digital (A/D) converter having a 256 channel capability. Each channel has differential inputs and are multiplexed. The converter mounts on standard 19" RETMA rails. The converter is normally mounted in the computer rack with the master controller.

#### 7.4 Specialized DCE Hardware, Data Handling Techniques

Because of the unique system design goals related to digital simulators, certain techniques have evolved which increase the flexibility of system design and economically provide more powerful means of accomplishing tasks than would otherwise be possible. As can be easily understood, while the digital computer has great versatility in implementing a simulation system, there are certain mundane but necessary tasks which can be carried out more efficiently outside the computer rather than within. The more salient of these items are:

1. Hardware bit processing to pack and unpack digital words in order to collect or distribute boolean bits.
2. Providing, external to the computer, word storage registers containing analog output data for ultimate conversion to analog signals.
3. Provide the capability for Block transfers of data into or out of the CPU to any selected DCE device with input or output commencing at any program selected DCE channel.
4. Provide hardware which will accept a digital word representing an angle and provide the sine of that angle as a digital output.

##### 7.4.1 Bit Processing

Under software control, via the control lines from the CPU to the DCE system, the particular device type is selected for a block transfer in the normal way except the additional device types are added as noted -

DBI (Digital Bit Input)

DBO (Digital Bit Output)

For input transfers, the DCE control logic thus enables the DCE controller to take one DCE DI word of n bits and input it to the computer on a one bit per CPU Byte or one bit per CPU word basis.

For output transfer, the DCE control logic thus enables the DCE controller to accept n Bytes or n words from the CPU and form them into one n bit DCE word for output transfer to the simulator interface.

Particular design details must, of course, be based on the actual computer and its hardware design features.

Characteristics and attributes of this device are as follows:

1. The basic transfer rate is  $1\mu$  sec for each 16-bit digital input or output word (DWI or DWO) and  $8\mu$  sec for each block of 16 digital bit inputs or digital bit outputs (DBI or DBO).
2. DBI's and DBO's must be transferred in blocks of 16 Linkage Word bits.
3. Packing and unpacking is completely under software control.
4. Based on specific design detail and computer instruction implementation, the DCE can accept computer bytes or whole words set to the Boolean value, or only the most or least significant bit of the computer byte or word. The converse is also true for input formats.

The hardware bit processor relieves the CPU hardware and software of the necessity of packing and unpacking boolean bits, and therefore reduces total CPU time otherwise required.

It provides increased overall system flexibility.

The amount of I/O core required is increased, and the overall DCE data throughput rate is reduced. However, this is not considered significant in relation to the total data transfer accomplished each frame.

The minor reduction of effective throughput is a valid tradeoff against the saving in program time otherwise required to unpack DI words or pack DO words within the CPU.

This technique is utilized fully in the Singer-SPD "T" Linkage as well as the SPD Linkage system being used on the 2F101 (T-2C) simulator. Present existing designs provide for a transformation of each 16-bit linkage DI word into 8, 16-bit computer (PDP-11 series) words. Each computer word is composed of 2 8-bit bytes.

#### 7.4.2 Analog Output Channel Data Storage

Until recently, with the advent of low cost D/A converter modules, the cost of D/A converters was such that a sample and hold technique was the only cost effective way to design and build analog output DCE systems having the large numbers of channels required by a large simulator (100 to 400 channels).

It is now economically sound to configure an analog output

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system having modular D/A converters and digital word holding registers for each channel. By designing packaging to permit the necessary flexibility, the resolution of the digital data can be economically maintained at 16 bits for all channels. However, less expensive 12, 10, 8, or 6 bit converter modules can be utilized in discretely selected channels as required, to provide a more cost effective total system.

Some of the characteristics of these devices are:

1. Currently designed to accept 8, 10, or 12 bit resolution converters interchangeably.
2. Currently designed with a 16-bit holding register for each channel.
3. Basic digital data transfer time increased to  $1\mu$  sec per channel exclusive of actual converter settling times.

This results in an extremely cost effective system by comparison to other techniques.

Assuming a DCE Controller with the capability of analog output starting channel address and range, this technique overcomes a strong disadvantage of a sample and hold technique in that continuous update is not required to prevent drift. With starting channel address and range, and with individual holding registers for each analog output channel, increased software efficiencies can, at least potentially, be realized.

With the addition of the individual holding registers it is possible to halt the CPU or single step without the consequent analog

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output signal ambiguities that result in a DCE system using the sample and hold technique. It is also technically feasible to increase the basic throughput rate to the analog output subsystem.

However, with respect to utilization of high resolution (greater than 12 bit) and high accuracy converters in this scheme it is not possible to establish a single set of  $\pm 10V$  references for the total system since each converter module presently available has its own internal reference and these cannot be slaved to a common system reference as would be expected in a total system design utilizing a large number of high resolution and accuracy converters. It is presently considered feasible to obtain families of converters having integral storage registers and it is reasonable to expect that new development will yield higher resolution units off-the-shelf in which a single 10 volt system reference can be utilized to improve overall system performance while reducing both long and short term drift.

Problems associated with a requirement to have a common 10 volt system reference are not considered to be necessarily relevant to most simulator applications since accuracies normally required are not stringent as those encountered in such high precision systems.

Singer-SPD's S3A simulator currently utilizes an analog output subsystem configured as described. It is basically a pluggable system in that the basic resolution and accuracy of any particular channel can be chosen merely by selecting the appropriate converter module. All

interconnected package interfaces are standardized within the system.

#### 7.4.3 Starting Channel Address and Ranging

This technique permits Block Transfers into or out of the CPU to any appropriate DCE Device type with input or output commencing at any program selected DCE channel. The transfer is then carried on via the CPU DMA controller until its word count register is decremented to zero or the program issues a "transfer terminate command".

Characteristics of this technique are as follows:

1. In the specific DCE systems currently designed, the technique is implemented by utilizing a 16 Bit control word as the first word of each Block Transfer from core to establish the starting channel address.
2. Additional I/O time of approximately  $1\mu$  sec for each block of data transferred is required in order to transfer the control word required.
3. Range is established via I/O program control of the word count loaded in the DMA device controller of the CPU.
4. The Real Time I/O Program can override the flag from the Device Controller and terminate the Block Transfer at any time.

This technique provides overall system flexibility in that update rates for the various DCE hardware channels can be made a function of software control only. (If Block Transfers to a particular DCE Device type must always start at channel 0, then devices in the



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simulator which require the highest update rate must always be hard wired as the lowest numbered channels since only range is a controllable parameter.)

Software change flexibility is provided in terms of multi-vehicle configuration simulation growth potential of the DCE system itself, and automatic DCE testing.

The I/O Data Blocks must have an additional control word.  
(The starting channel number must be in the I/O Data pool.)

This technique is currently implemented in the Basic Designs of Singer-SPD's "T-Linkage" and the Linkage used for the 2F101 (T-2C) simulator.

#### 7.4.4 Hardware Sine Conversion

The hardware device consists of the necessary digital logic to accept a digital word representing an angle in degrees as an input from the computer and provide the sine of that angle as a digital word at its output back to the computer.

The hardware converter is thus functionally utilized in place of a software subroutine.

In simulation applications, the device is applicable to computing the digital data words required for D/A/R (Digital to Analog to Resolver) and D/A/S (Digital to Analog to Synchro) conversion devices.

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Some of the device characteristics are as follows:

1. High Accuracy (14 Bit input and output) for simulation purposes.
2. Minimizes computer time in direct proportion to the number of Resolver/Synchro Devices in the simulator.
3. Can also be used for other sine subroutine computations not directly related to the DCE equipment.

Implementation of the technique can substantially reduce computer loading in simulators utilizing large numbers of D/A/R's and/or D/A/S's.

Singer-SPD's simulators currently utilizing the SPD "T-Linkage" also use a hardware sine converter operating as a CPU peripheral device interfaced to a program controlled device channel on the CPU (PDP-11 series).

### 7.5 Recommended DCE Configuration

The principle tradeoffs worthy of serious consideration in selecting a DCE configuration are:

1. Non-recurring and recurring cost and complexity
2. Reliability/Maintainability requirements
3. SMS requirements in terms of layout, growth, versatility, etc.
4. Program risk, both in the area of technical development and maintaining an optimum program plan as established.
5. Operational speed and I/O time
6. Long term system versatility
7. Minimization of long term operating cost and complexity with respect to changes which may be required in the SMS hardware and software above an initial delivered configuration.

The DCE system should have the potential of satisfying both short and long term growth potential, with the growth potential being additive at minimum cost and calendar schedule impact.

Weight and space requirements preclude the mounting a large DCE equipment on the motion system platform.

The number of cables and connections required for a completely centralized linkage is very high.

At the present point in time, and based on the state-of-the-art of development of centralized and distributed DCE systems, it is recommended that a modified distributed DCE system configuration be utilized in the SMS.

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This system will take the form of the "T" Linkage DCE described in Section 7.3.2, but will be distributed to the two crew stations, to the instructor operator stations, and to the ancillary equipment, motion, and visual system cabinet areas.

Figure 7.5-1 is a block diagram of the presently recommended SMS DCE configuration.

Future developments in MSI and LSI circuitry in the next year or two may allow development of a more completely distributed DCE system capable of closed loop test, economically and with lower risk than at present.

It is also recommended that hardware bit-processing be provided, and that the analog output system include the buffered storage technique to provide increased performance flexibility and at least potentially, reduce software loading. Starting channel address and ranging should also be considered a mandatory requirement of the DCE system to provide the inherent system flexibility it offers in comparison to cost or complexity.

In addition present estimates indicate that the total SMS requirement for Electronic Synchro Resolver Drivers is approximately 270. At twenty iterations per second, the implication is a calculation of 5400 sine functions per second. The average execution time of a sine function subroutine is approximately 100 microseconds. Hence, approximately 540,000 microseconds per second of time could be required for this function in the mini-computer.

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which drives the D.C.E. A hardware sine function generator is therefore recommended to supplement the D.C.E. mini-computer. This device has been developed and provided on several commercial simulators and has proved to be a very economical accessory to the D.C.E. system.

Analog and Digital I/O have been divided into groups coincident with the major SMS sections as shown. This will allow independent test and maintenance of the various sections and also reduce the number of cables and connectors required for the D.C.E. Closed loop testing of the D.C.E. will also be incorporated.

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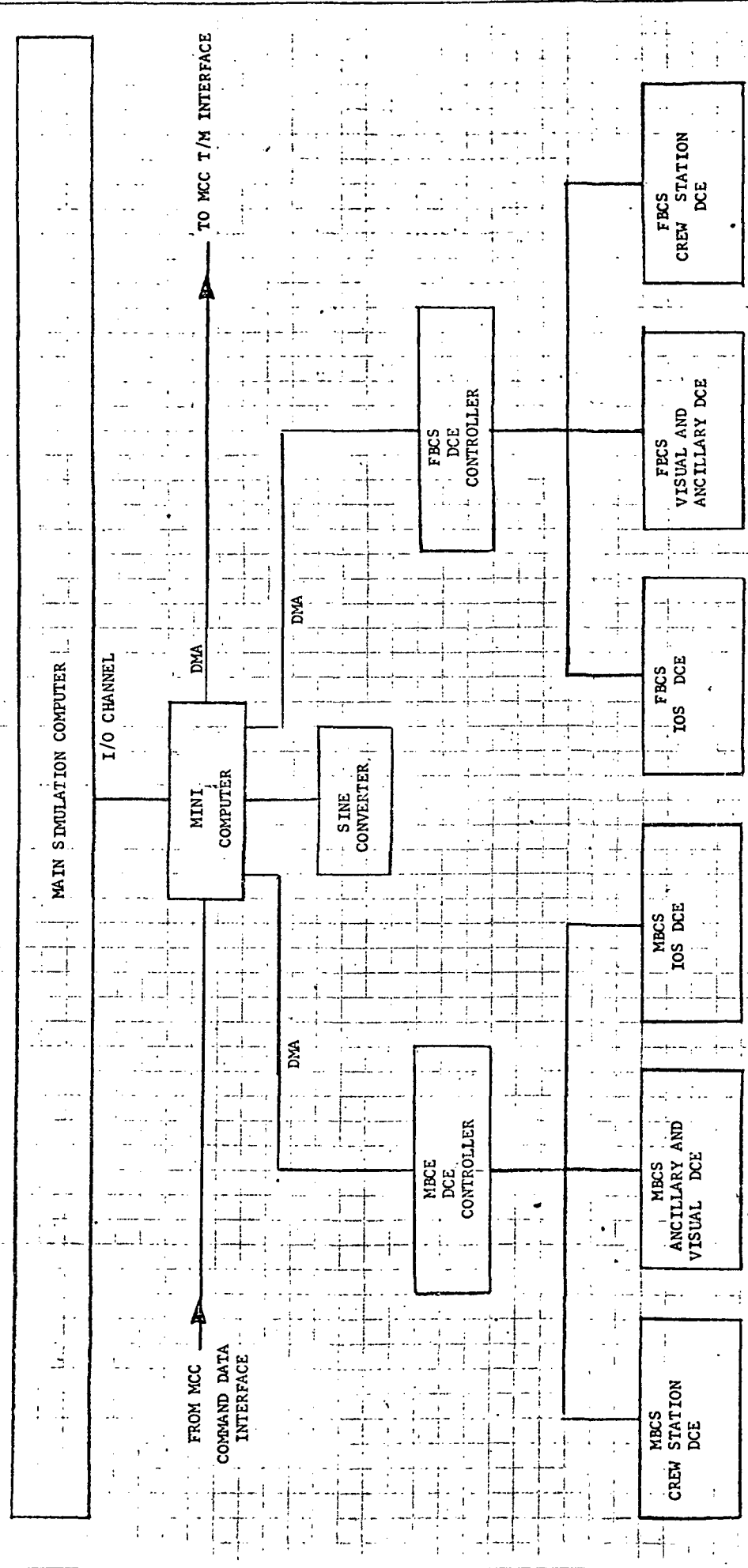


Figure 7.5-1 RECOMMENDED SMS DCE CONFIGURATION

## 8.0 Tradeoffs and Recommendations

### 8.1 Motion System

The detailed in-depth analysis of motion systems requirements coupled with crew station configuration and visual system requirements which has been accomplished in the SMS Study has resulted in the recommendation for a state-of-the-art motion system with an added tilt feature as described in Section 3.1. This approach to motion simulation, based on the requirements for motion only during the aerodynamic flight phase of the Shuttle Mission, has been shown to be a viable and extremely cost effective approach.

The only area of risk associated with motion simulation is the design and development of the tilt feature. This risk is not considered to be a major constraint. The non-recurring and recurring costs of providing the tilt capability are estimated to be less than twice that of a basic Six D.O.F. Motion System.

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## 8.2 Crew Station

The primary risk associated with the SMS crew station design and development relates to data availability and associated change activity. Procurement of E-L panels and special instruments may also present some problems related to the SMS delivery schedule especially if panel configurations are fluid.

At the present time design and manufacture of a SMS type crew station shell and secondary structure is estimated to take approximately 18 months, exclusive of Hardware/Software Integrated testing. It is recommended that the costs of crew station design be minimized by making the forward sections of the MBCS and the FBCS as nearly identical as possible.



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### 8.3 Instructor Operator Stations

Analysis of the SMS Instructor Operator Station requirements has resulted in a very well defined device with very few areas of risk. The only area of risk known is in relation to obtaining a high resolution, high accuracy, multi-color CRT system.

A tradeoff study has been completed related to the use of CRT page type displays versus dedicated repreater instruments which has attempted to optimize the instructor visibility while minimizing overall SMS cost. Details of this area are included in Sections 4.3 and 5.3 of this report.

#### 8.4 Ancillary Equipment

Risk related to ancillary equipment are not considered to impose any significant constraint on the SMS cost, performance, or delivery schedule. No new development hardware is anticipated and a normal design, manufacturing, and test schedule is anticipated.

Areas worthy of special attention are the SMS/MCC interfaces such as the Central Timing Interface, the Telemetry System Interface and the SMS Computer Interface with MCC.

The Telemetry Interface may impose a problem since the data rate has been increased from 51.2K Bits/Second on the SLS to 128K Bits/Sec. or possibly 256K bits per second on the SMS.

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## 8.5 On-Board Computers

An analysis of the four basic techniques for on-board computer simulation has been conducted as related to cost, risk, performance and training value. Techniques reviewed included use of real world hardware, translator/compiler, interpreter, and functional simulation. Refer to Section 6.4, Table 6.4-1 for an indication of the relative costs of these techniques. Although the values given are rough order of magnitude numbers and are not exact, they are the best that can be obtained at this time based on data available.

The functional approach and interpretive approach to DP&S simulation have been rejected because of the high risks and the fact that the SMS schedule will not support these techniques.

As shown in Section 6, Table 6.4-1 from a cost viewpoint, it can be seen that the use of real hardware for the DP&S system simulation is advantageous if the number of crew station simulators is limited. The real hardware approach is therefore recommended for simulation of the DP&S subsystem.

For the main engine controller computers, both the translator and interpreter approaches have been rejected because of the costs and risk involved. However, the estimated cost of the functional approach and the real hardware approach have been found to be nearly equal, i.e., assuming a functional simulation, the main engine is only used for a small part of the total Shuttle Mission, its simulation

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may be time shared with other programs and hence not incur an absolute cost on the main simulation computer for memory or CPU time.

If data related to the main engine controller computer program becomes available, and does not change significantly, the functional simulation approach will be viable and cost effective. This approach will eliminate three minicomputers from the SMS, with a resultant increase in overall reliability.

It is therefore recommended that the final choice of method for simulation of the Main Engine Controller computer be held in abeyance until more data is available.

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## 8.6 Data Conversion Equipment (DCE)

The DCE for the SMS is presently considered to be GFE and as such must be well defined early in the program in order to insure that a proper DCE/SMS interface can be provided.

Some computer vendors do not build data conversion equipment of the type and in the quantities required for the SMS. Hence this equipment might have to be subcontracted by the computer vendor with associated risks and increased costs.

An additional risk is incurred if additional DCE must be added to the SMS at a later date, since this can have a large impact on the SMS computer operating system overhead. It is therefore recommended that the DCE and associated minicomputers and controllers be included in the SMS simulator procurement.

To insure that the DCE be of a quality appropriate to the SMS and not be underbid during the proposal phase, it is recommended that the DCE be specified very explicitly in terms of quantity, signal characteristics, resolution, accuracy drift, etc.

Assuming that the DCE is provided by the SMS Contractor, the interface definition problem is alleviated and the DCE becomes a part of the SMS with a similar procurement and fabrication cycle. The DCE for a simulator of the magnitude of the SMS will require approximately 18 months to completely define, manufacture, and in-plant test. This must be followed by two months of on-site test to verify the main simulation

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computer interface and burn-in the hardware.

Performance requirements of the DCE are normally specified to meet the resolution, accuracy and time delay requirements of the simulation and hence enhance or detract from the training value of the simulation. At this time there are no special or exotic DCE requirements known for the SMS since the on-board data processing system is considered as a special case not requiring standard DCE equipment.

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SMS HARDWARE

CONCEPTUAL DESIGN REPORT

ADDENDUM A

CREW STATION PANEL LOCATIONS

AND OUTLINE DRAWINGS

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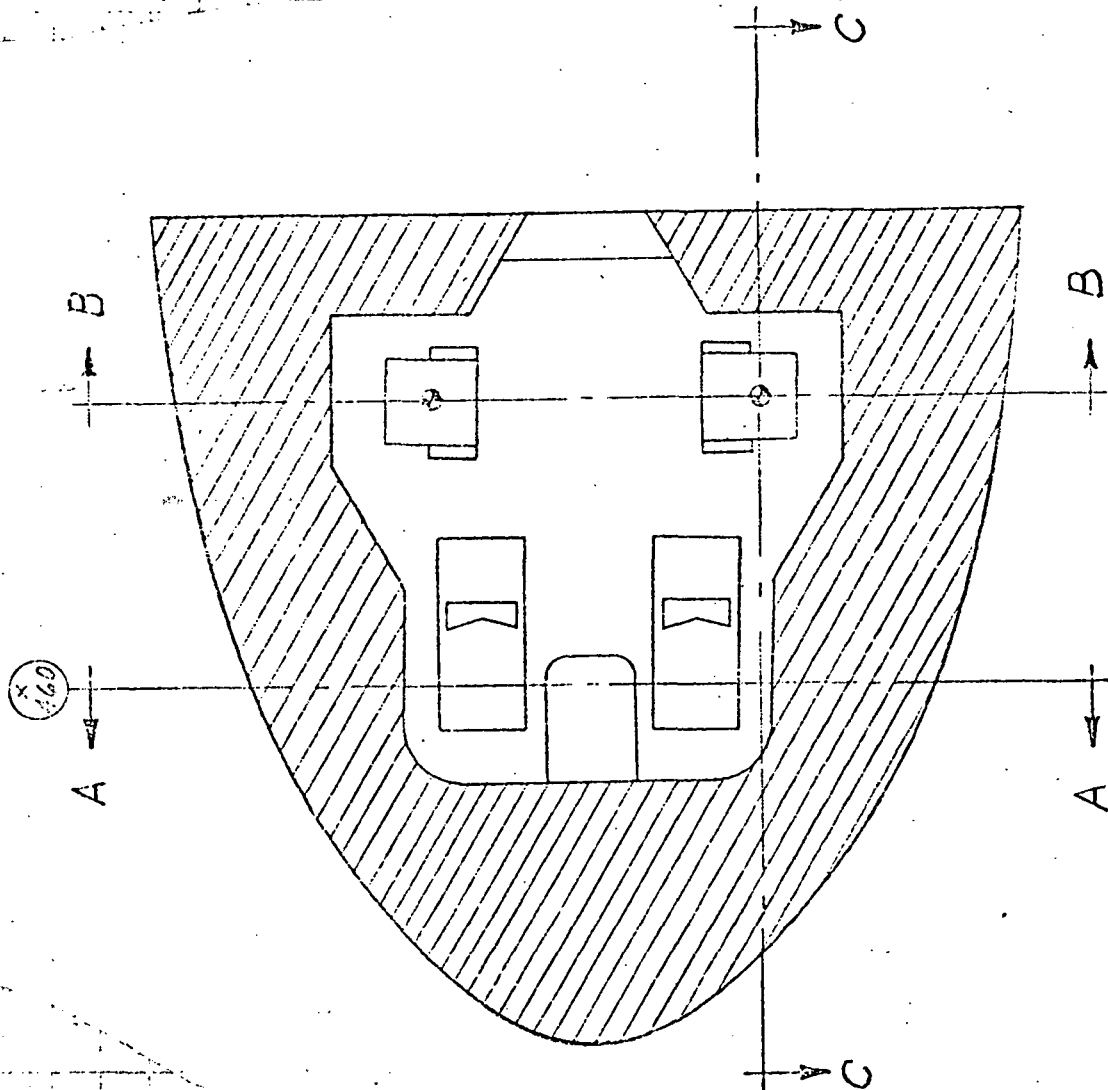
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CREW STATION



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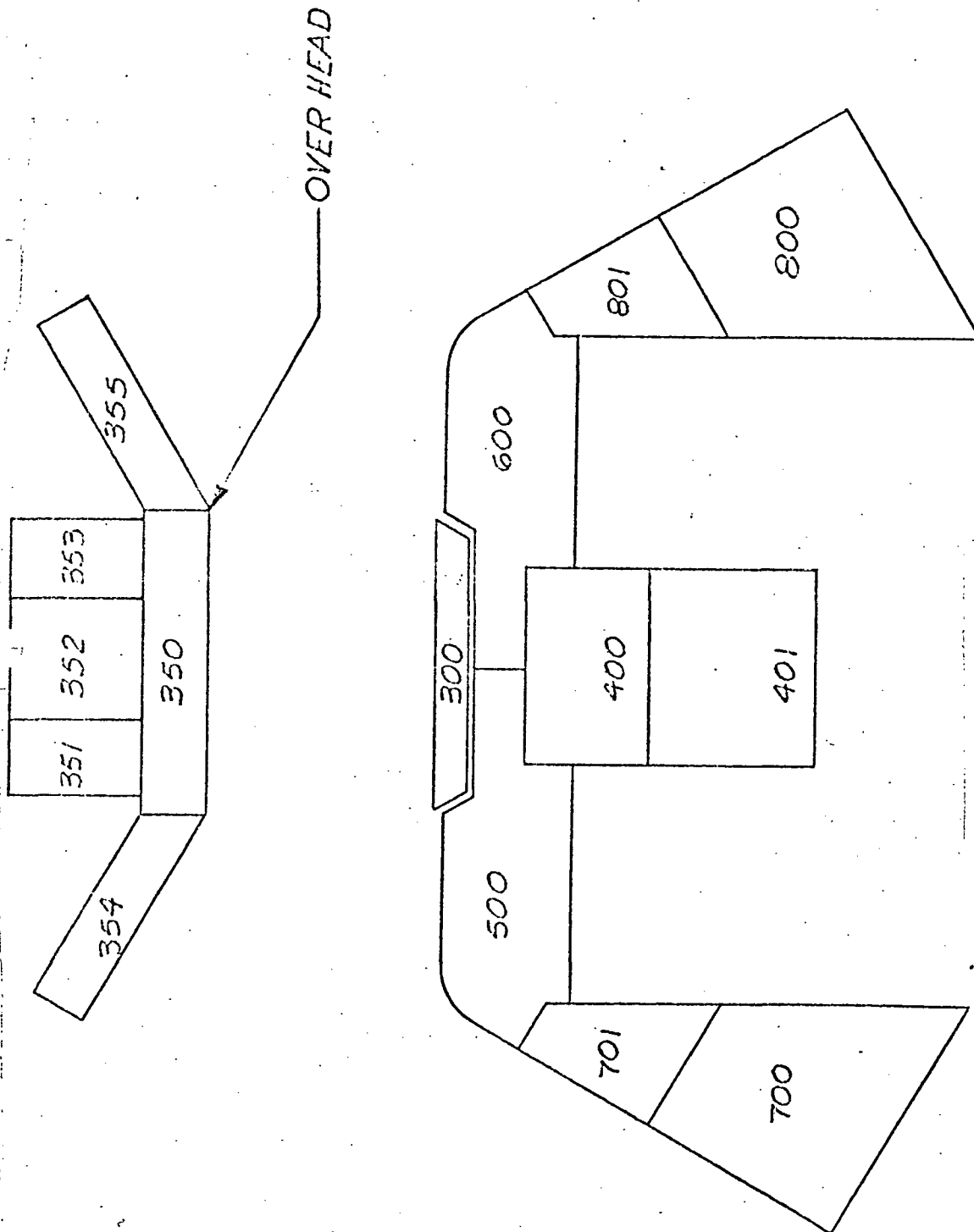
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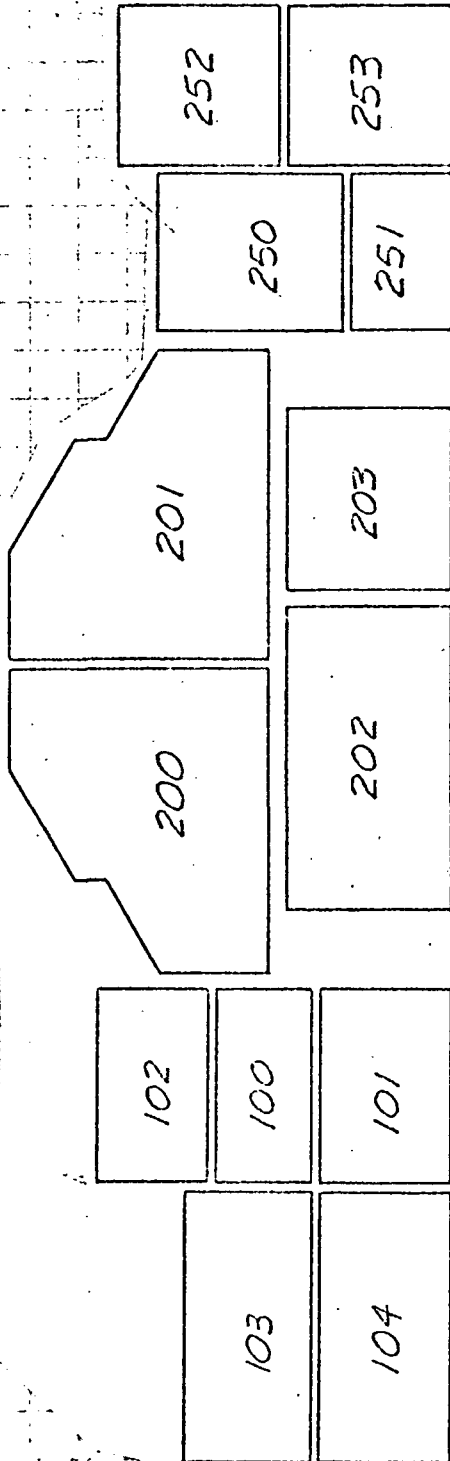
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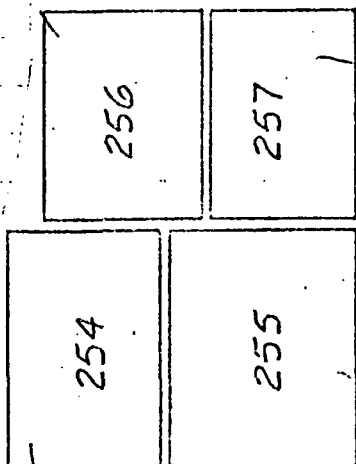
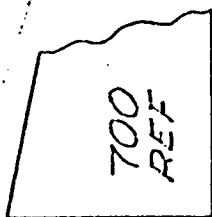
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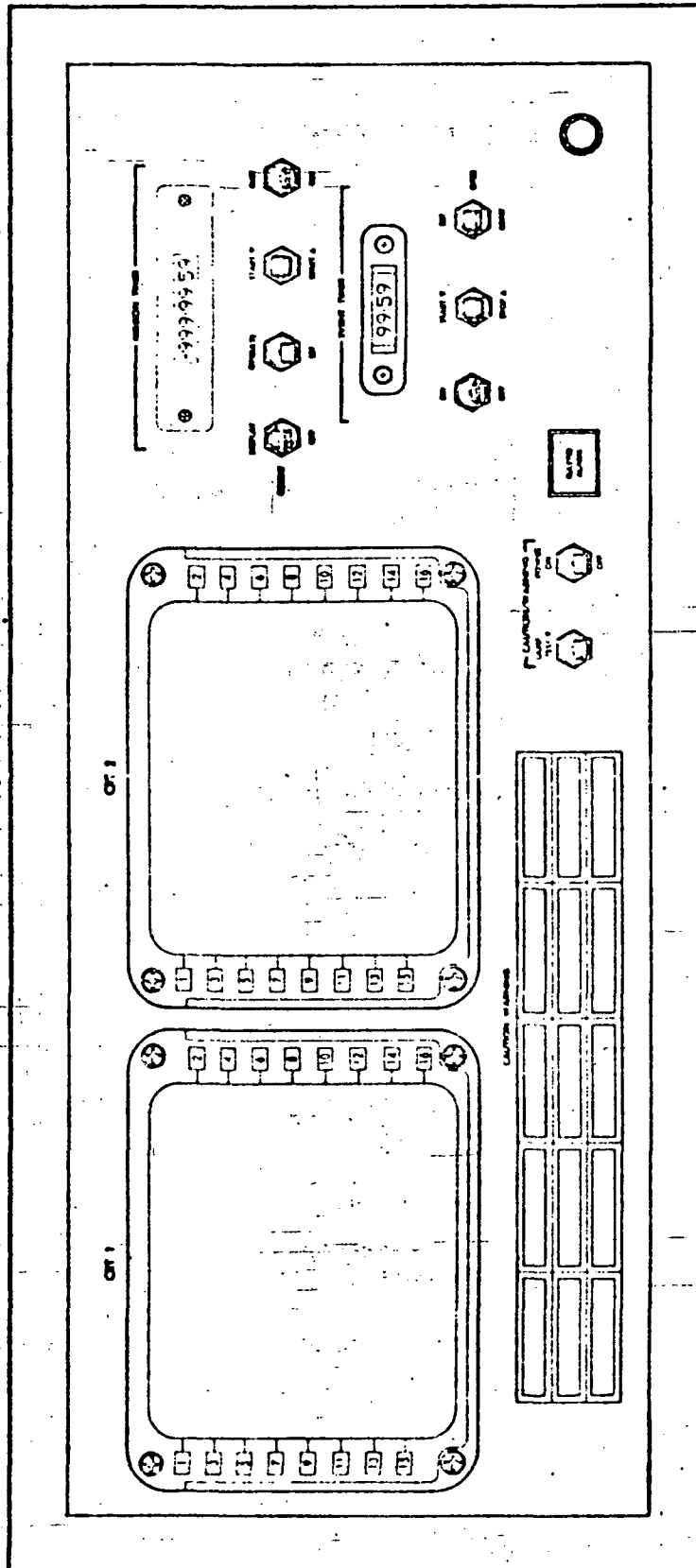
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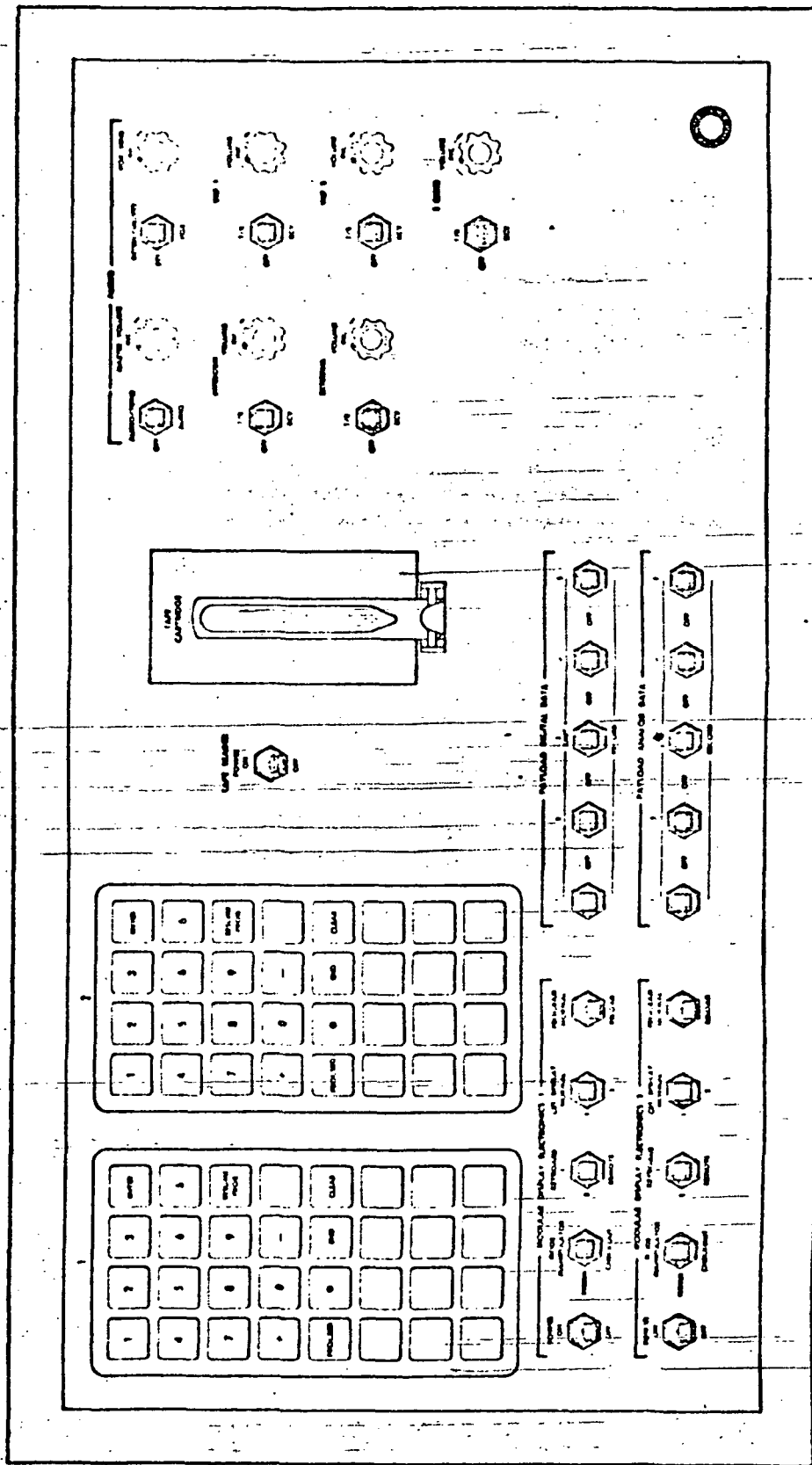
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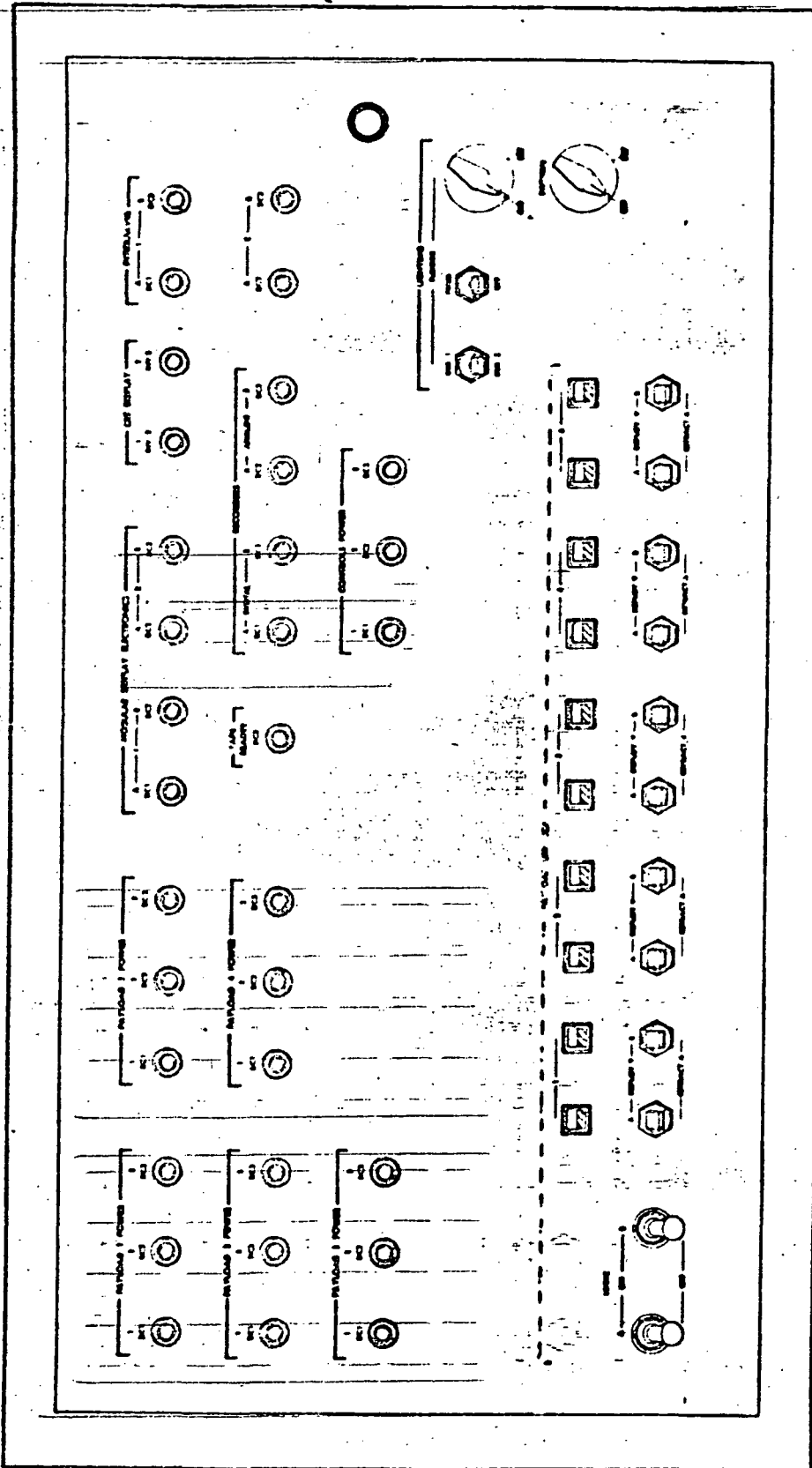
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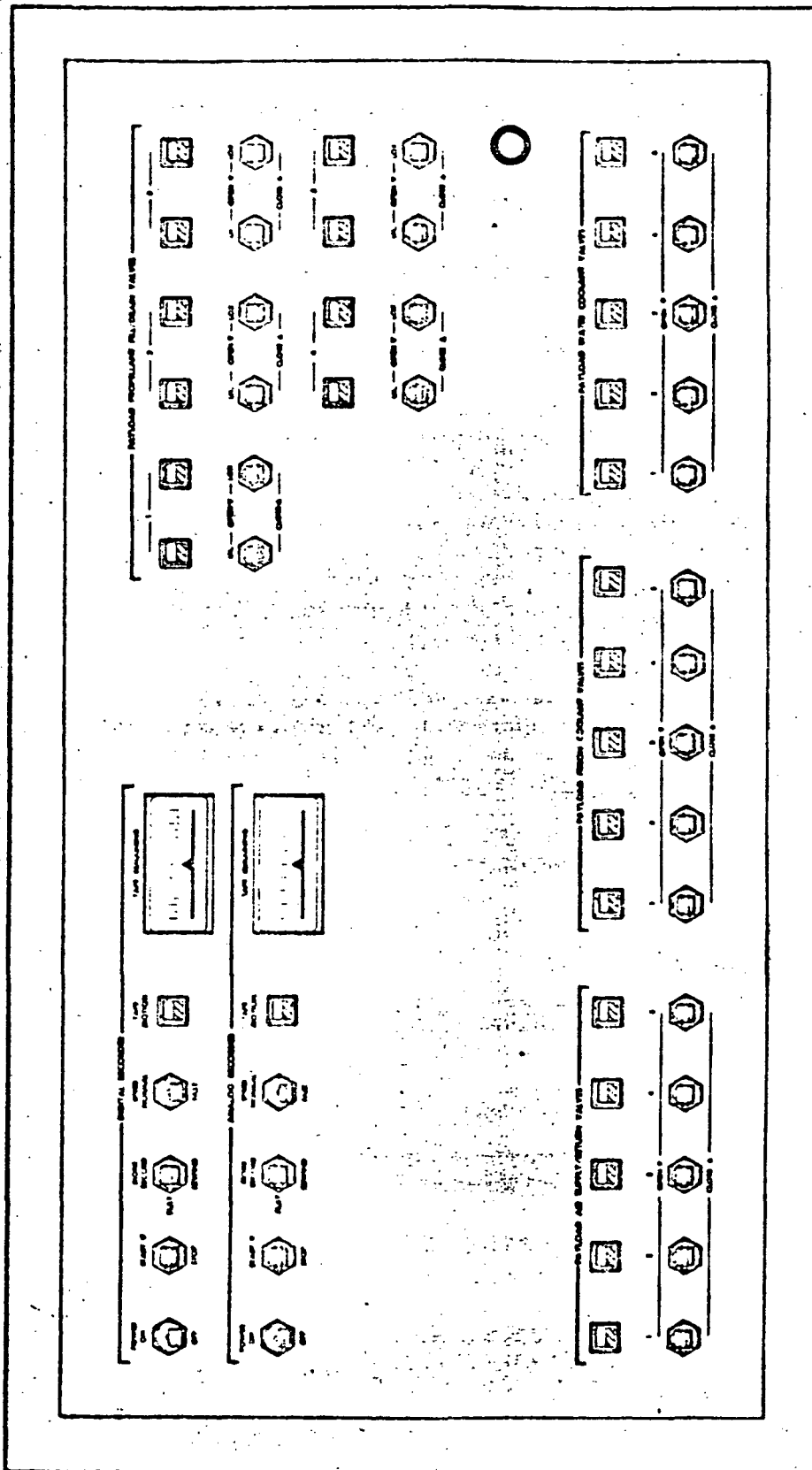
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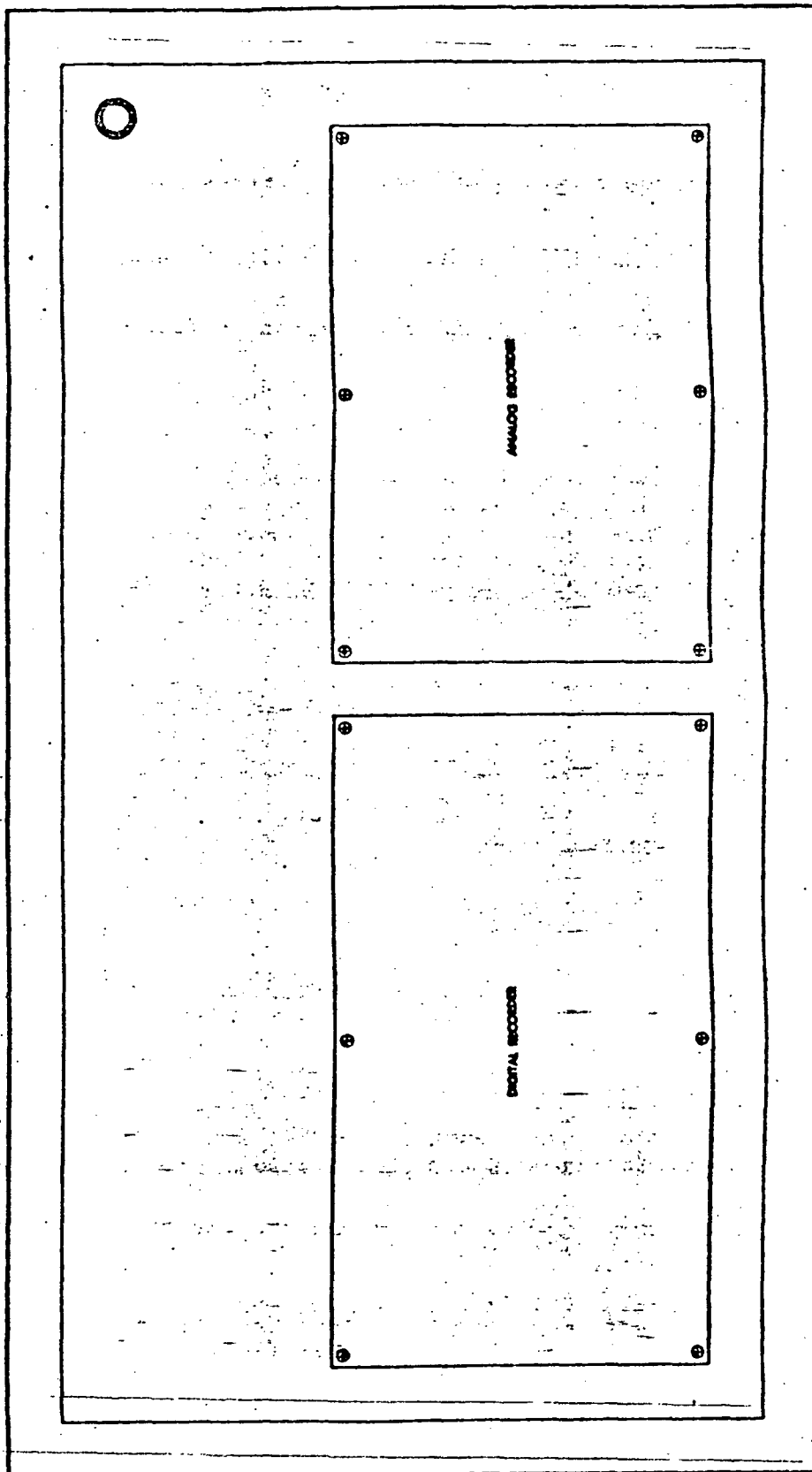
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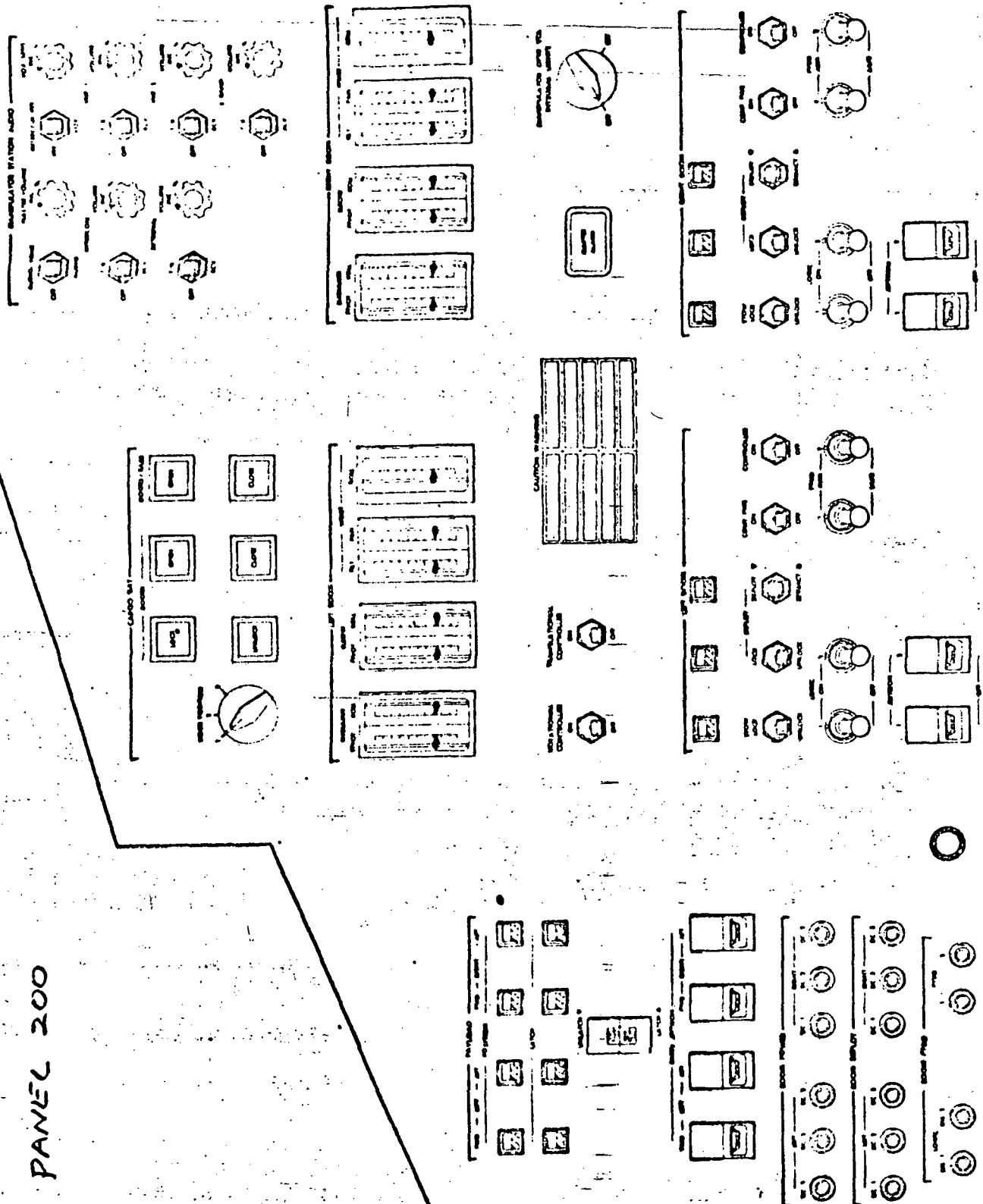
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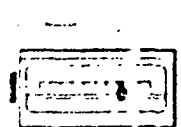
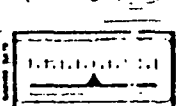
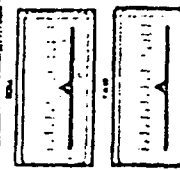
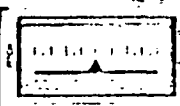
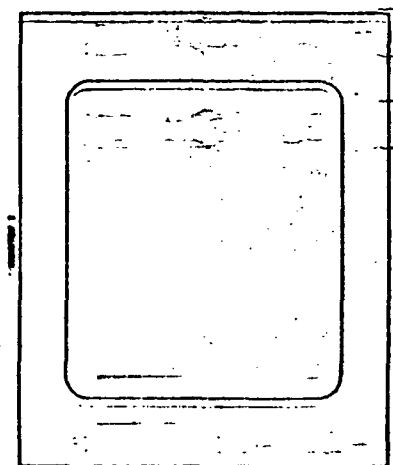
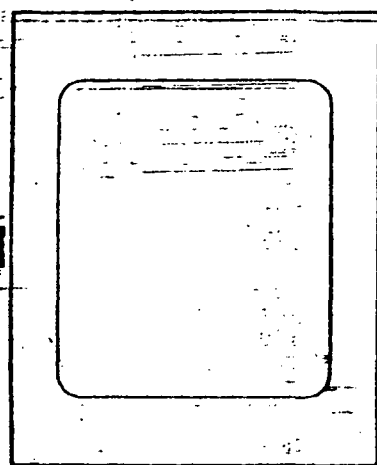
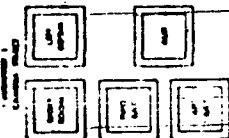
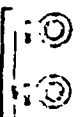
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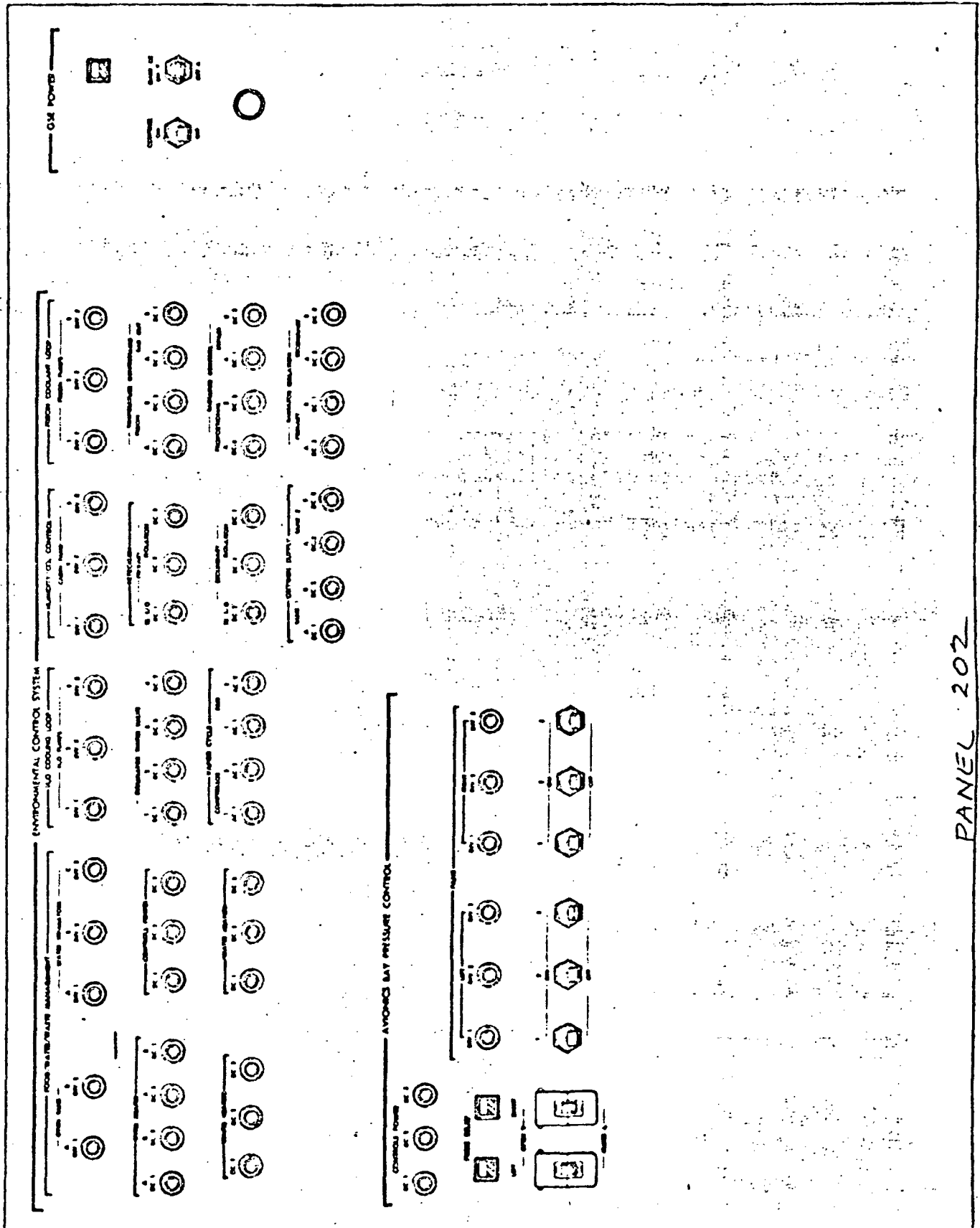
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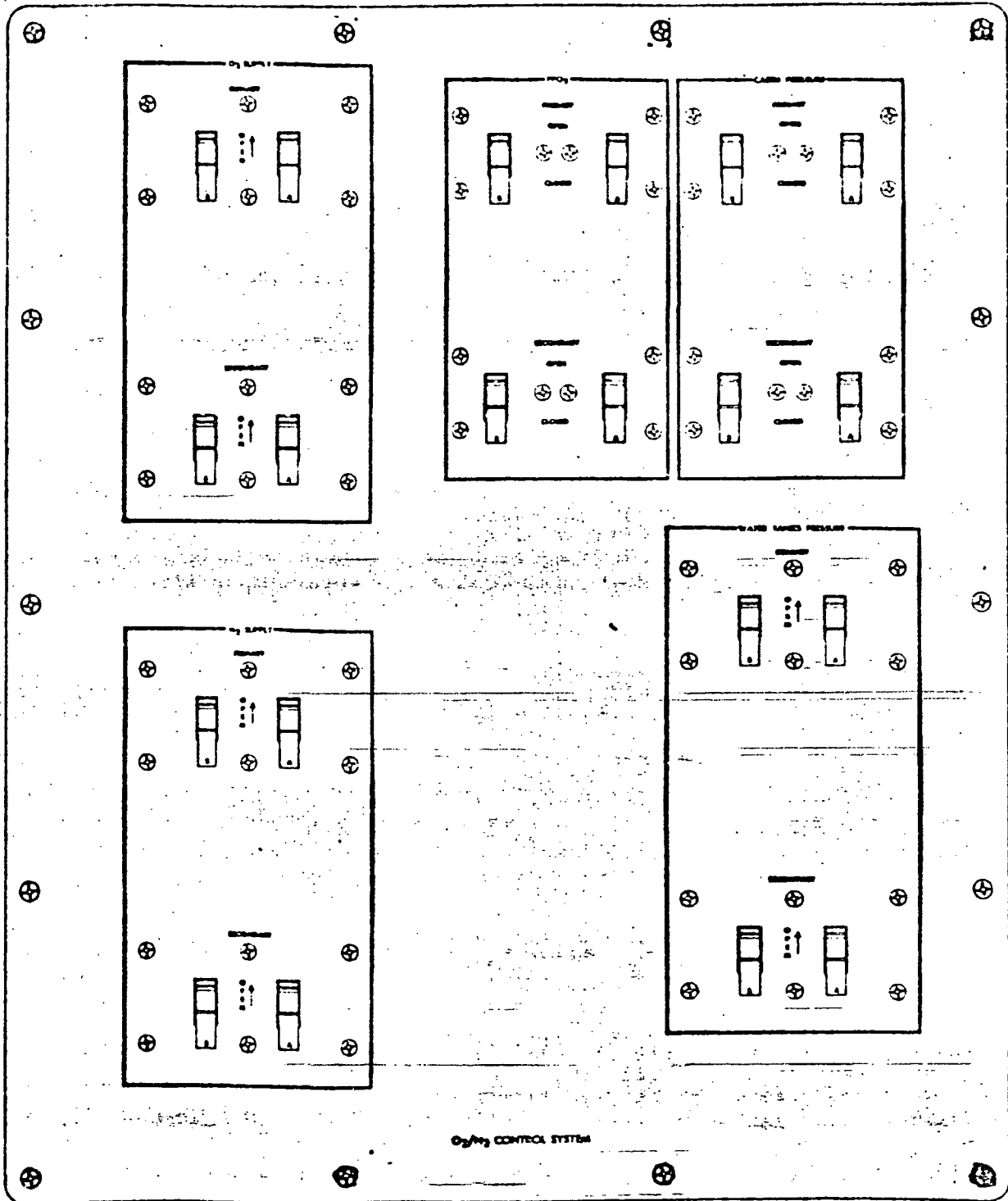
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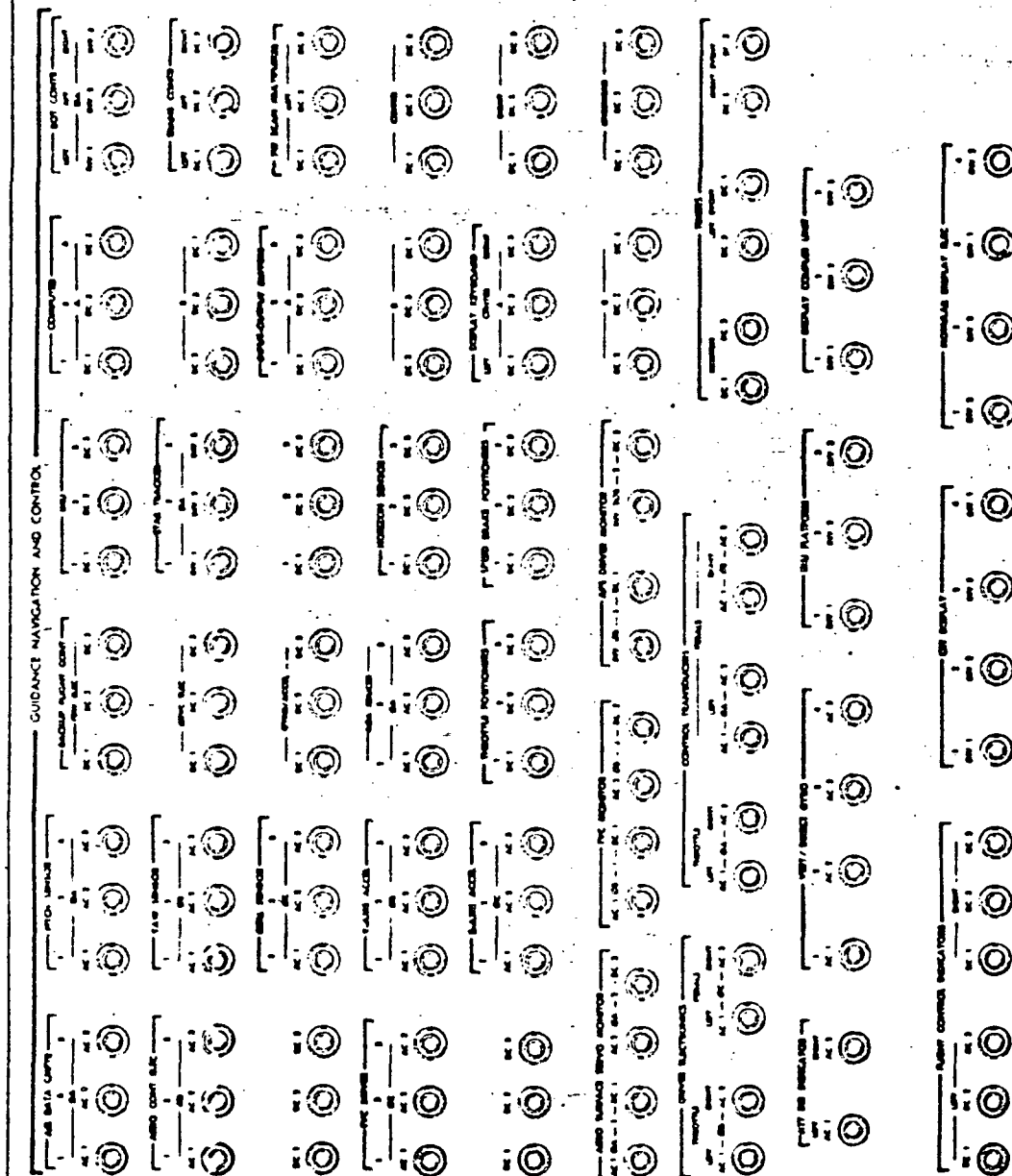


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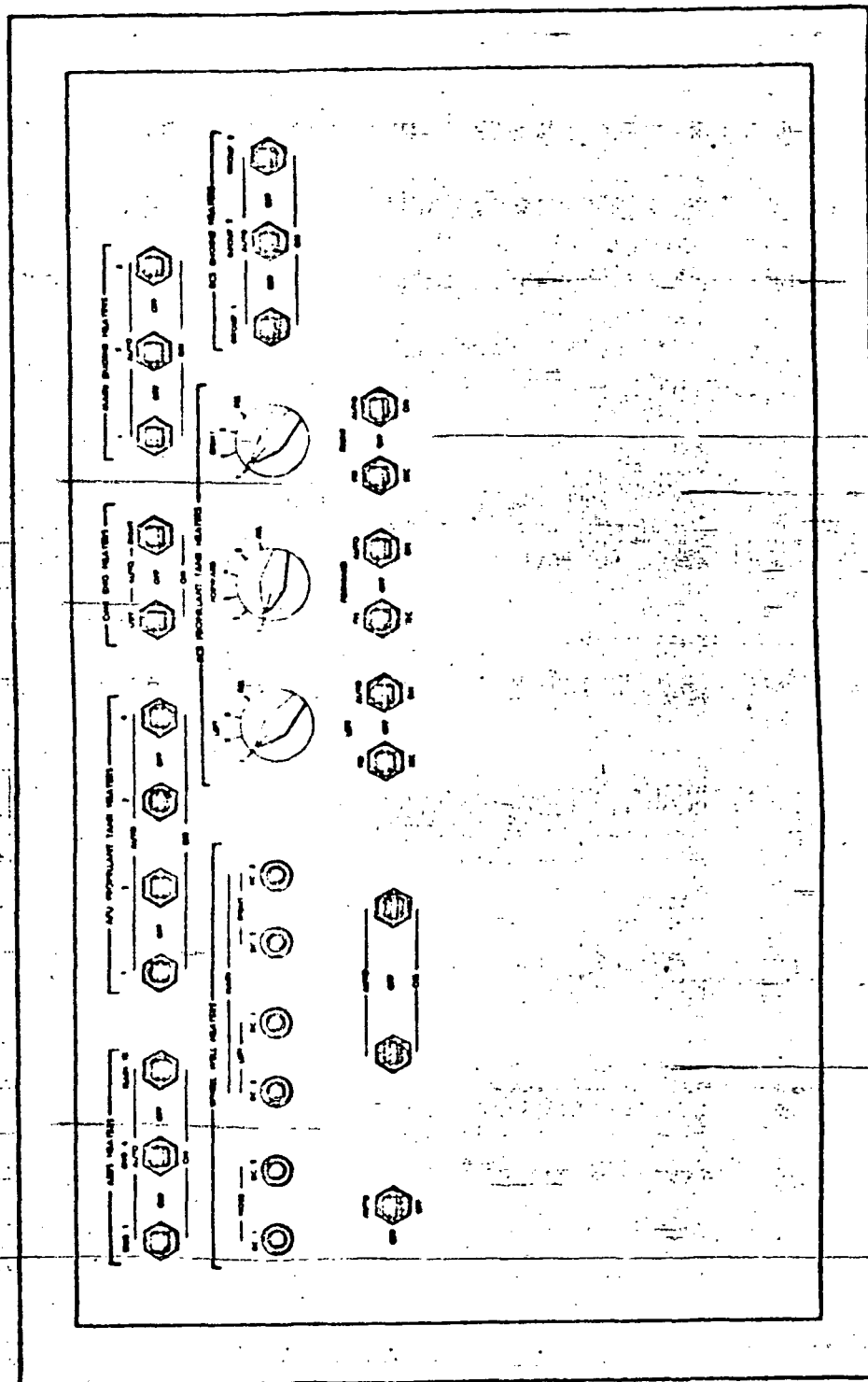
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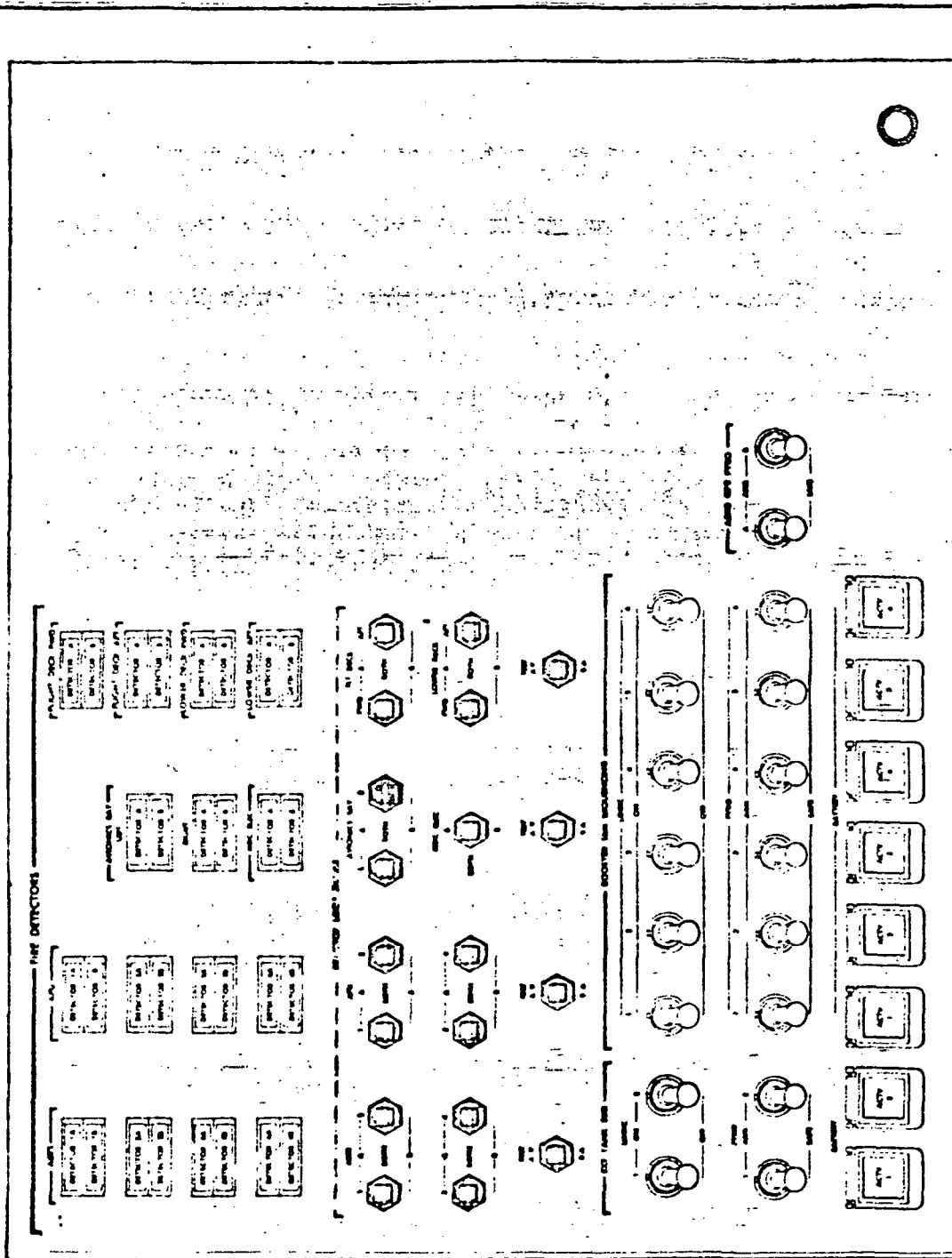
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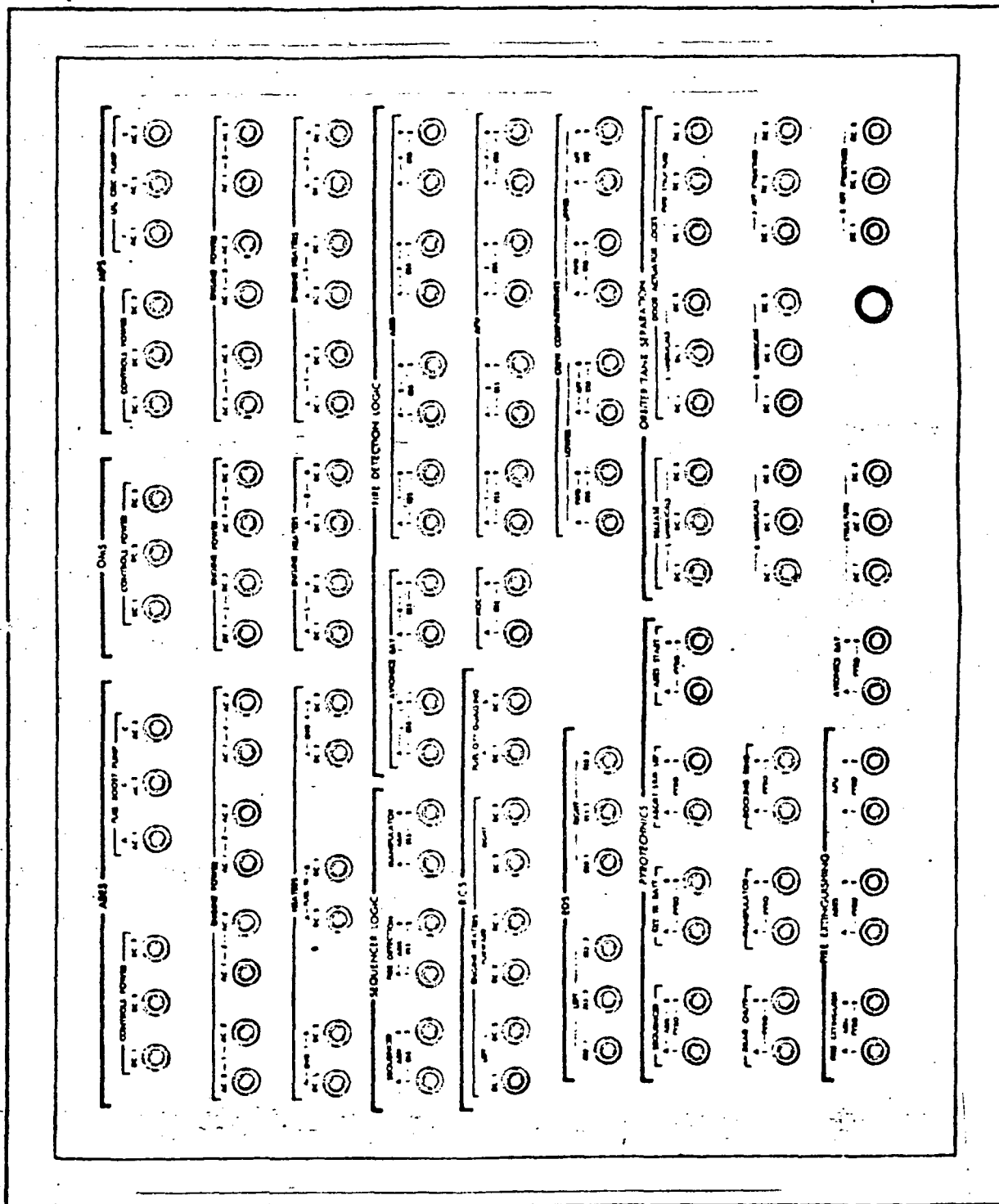
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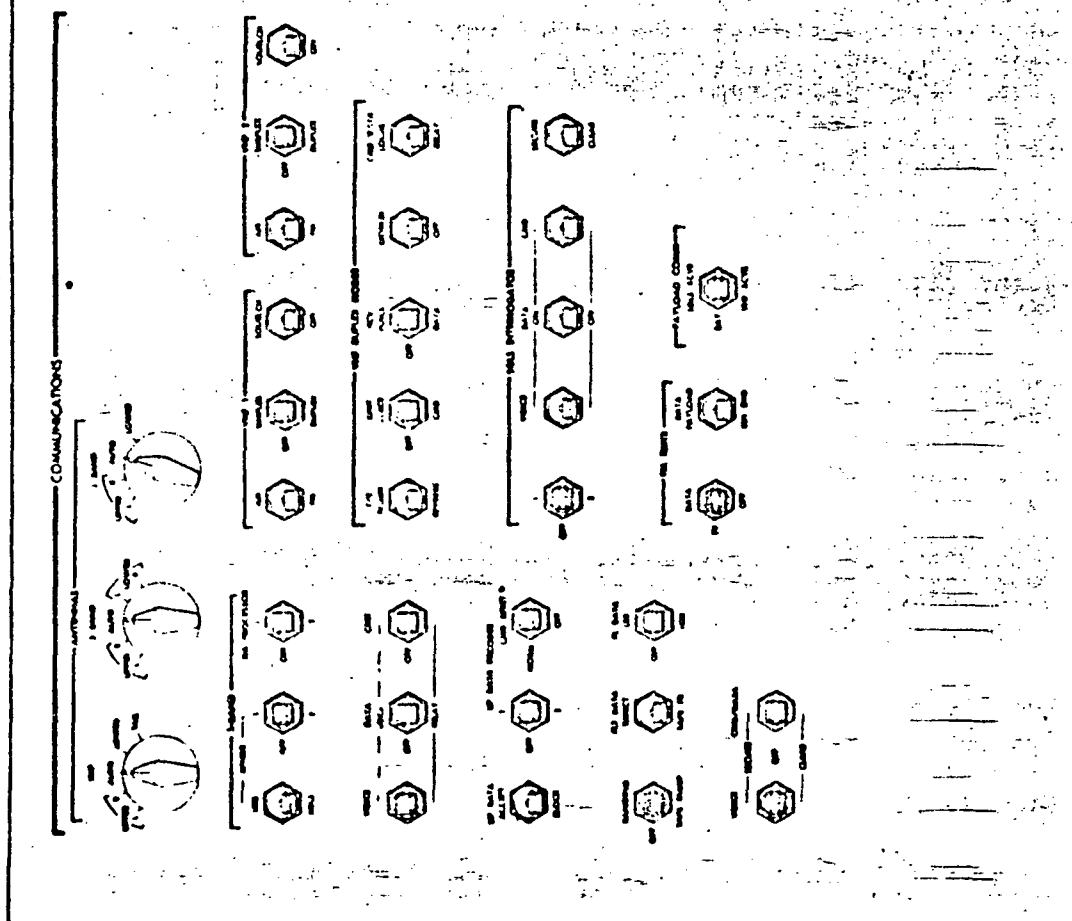
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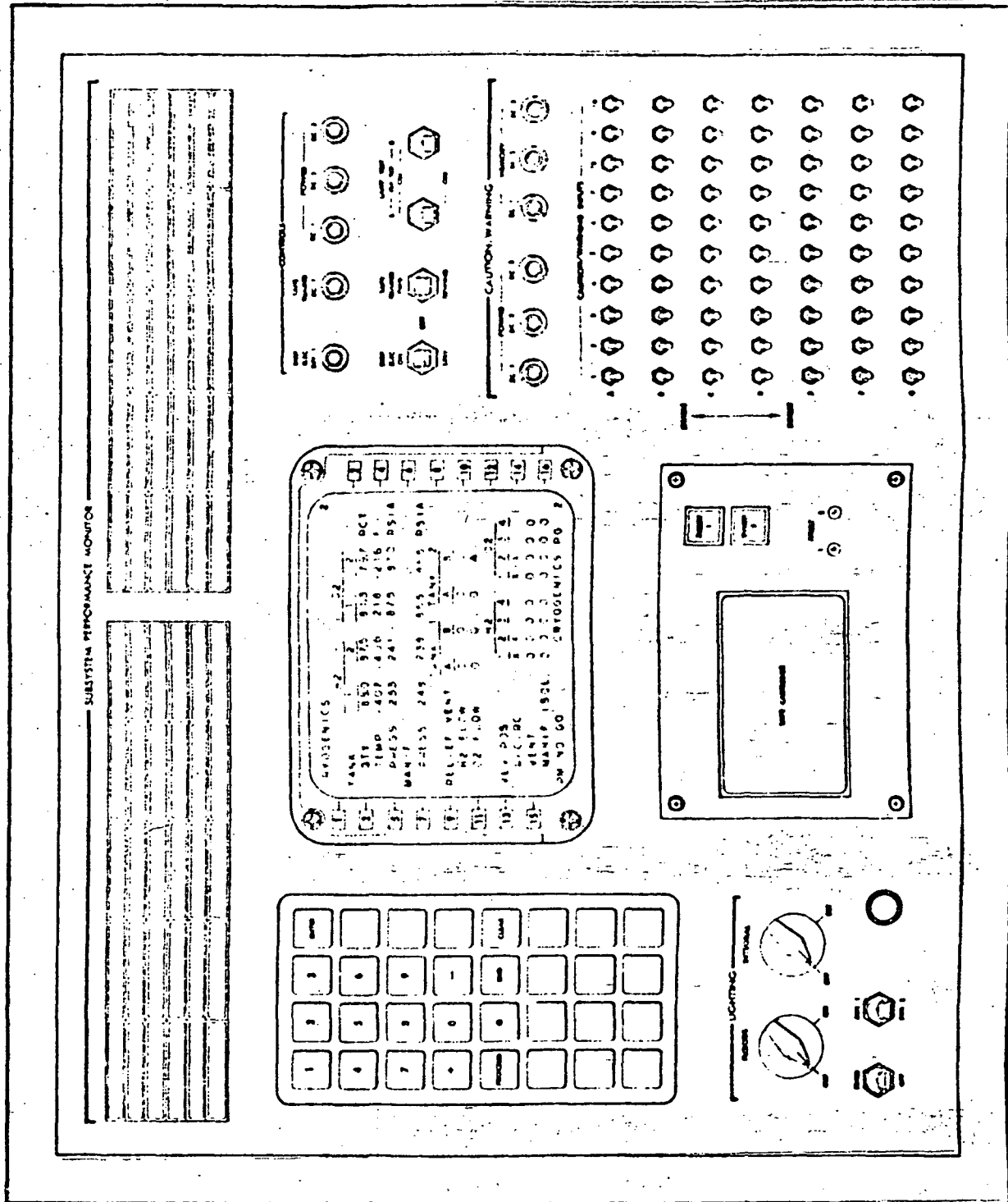
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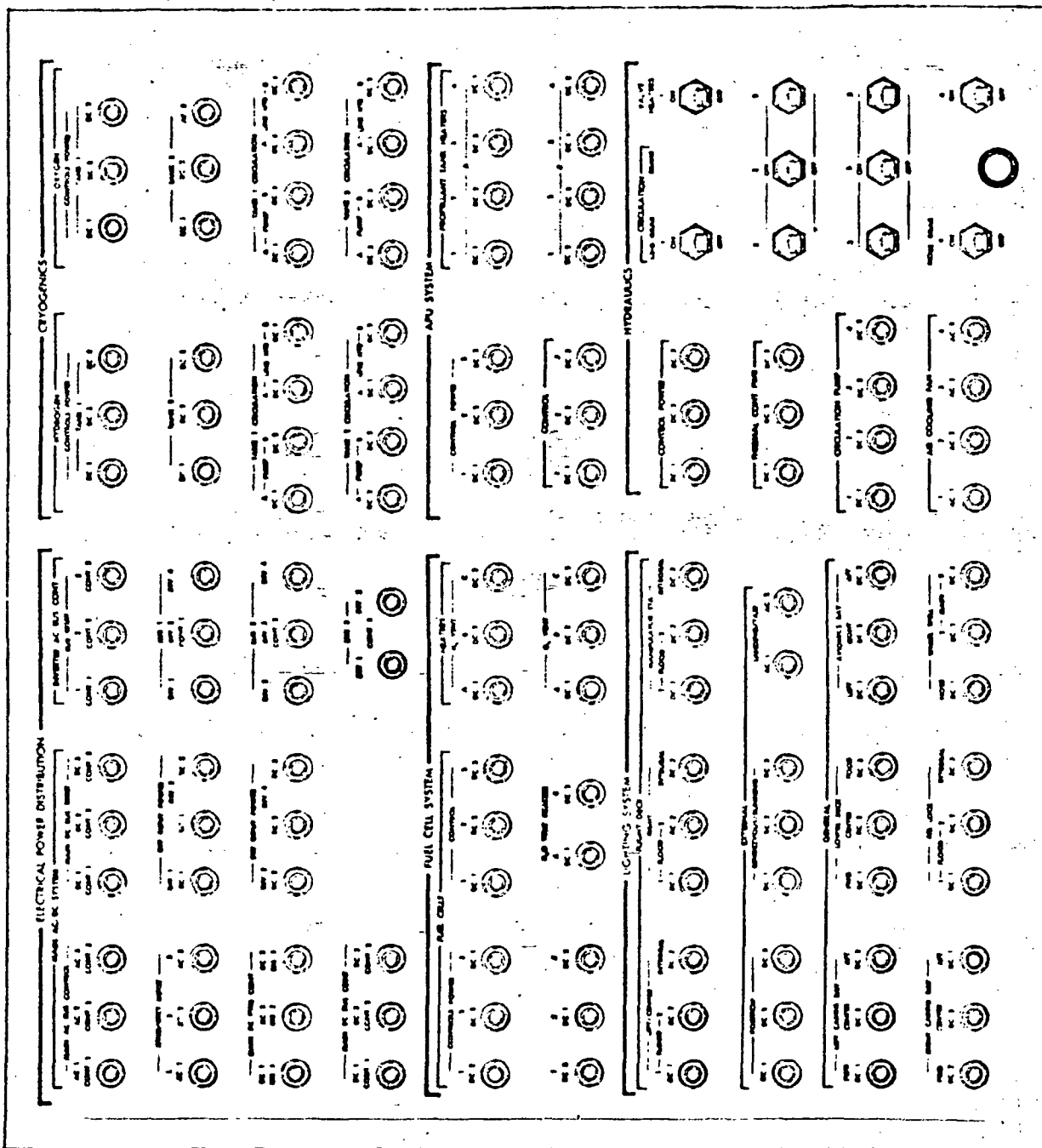
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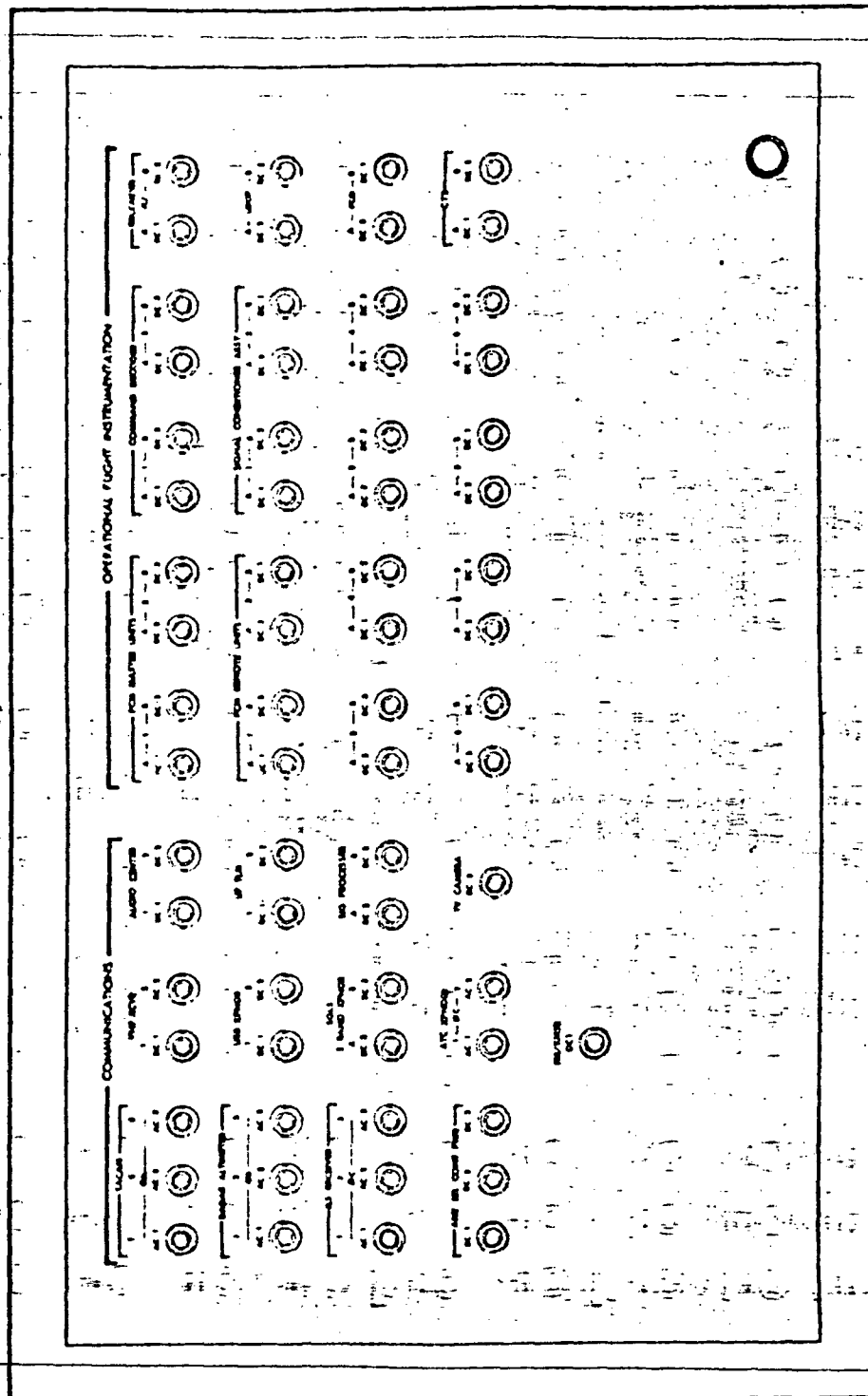
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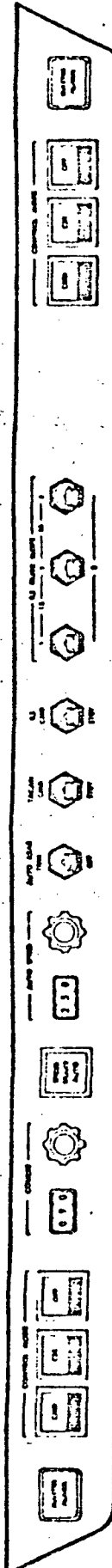
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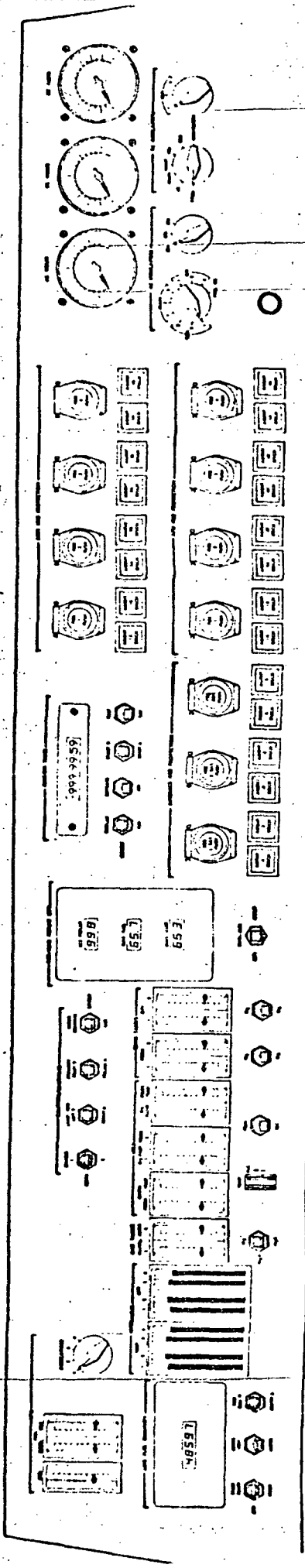
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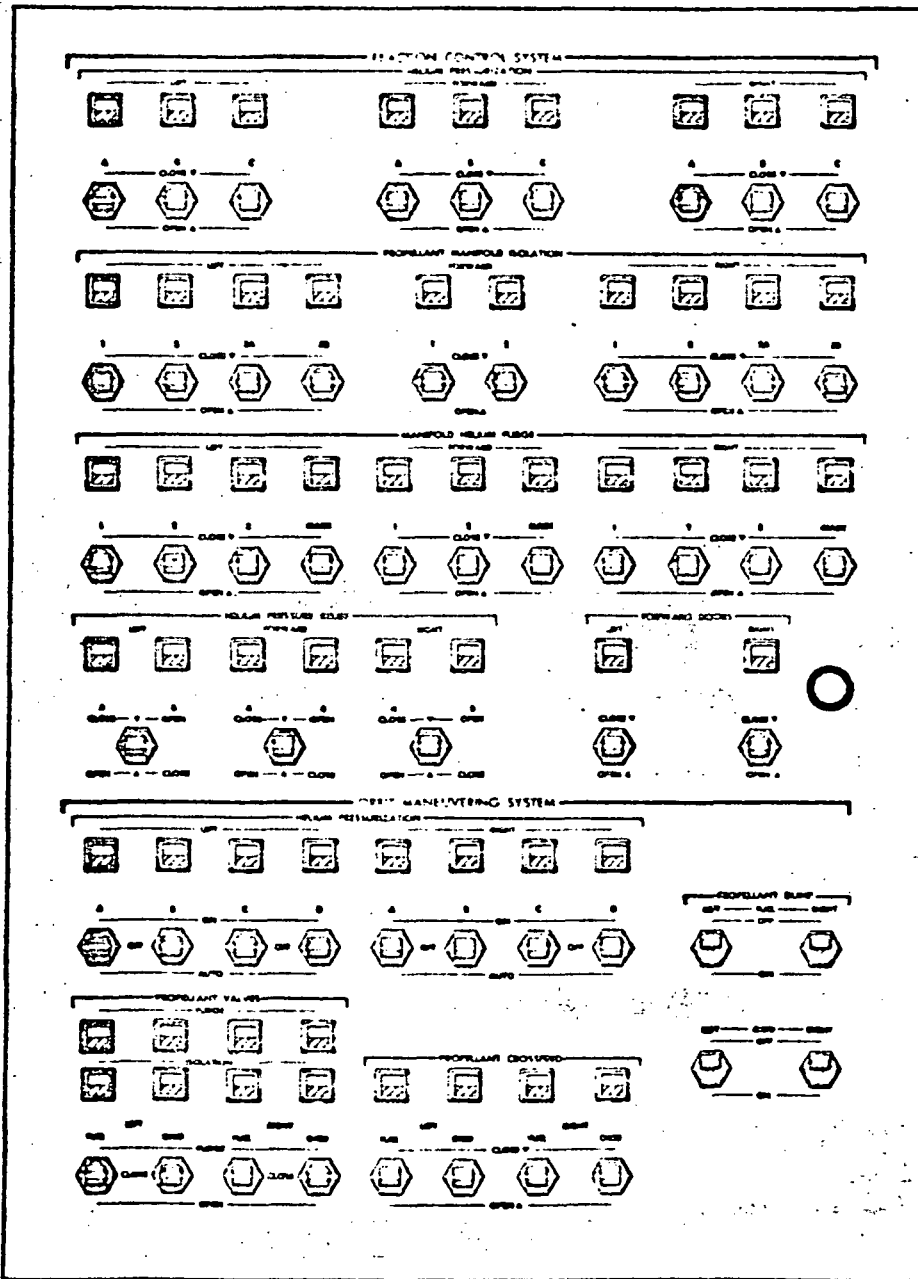
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PANEL 351

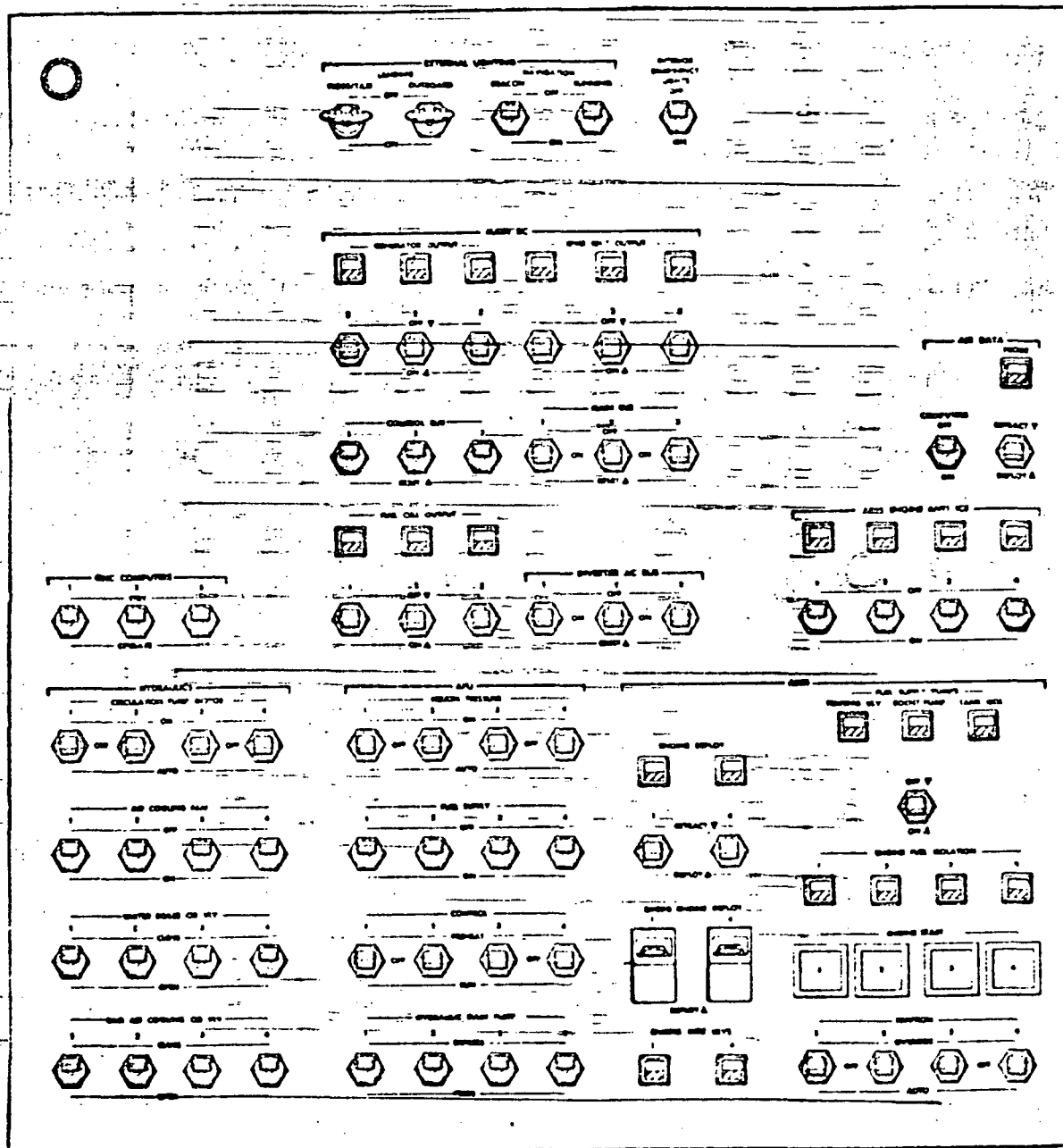
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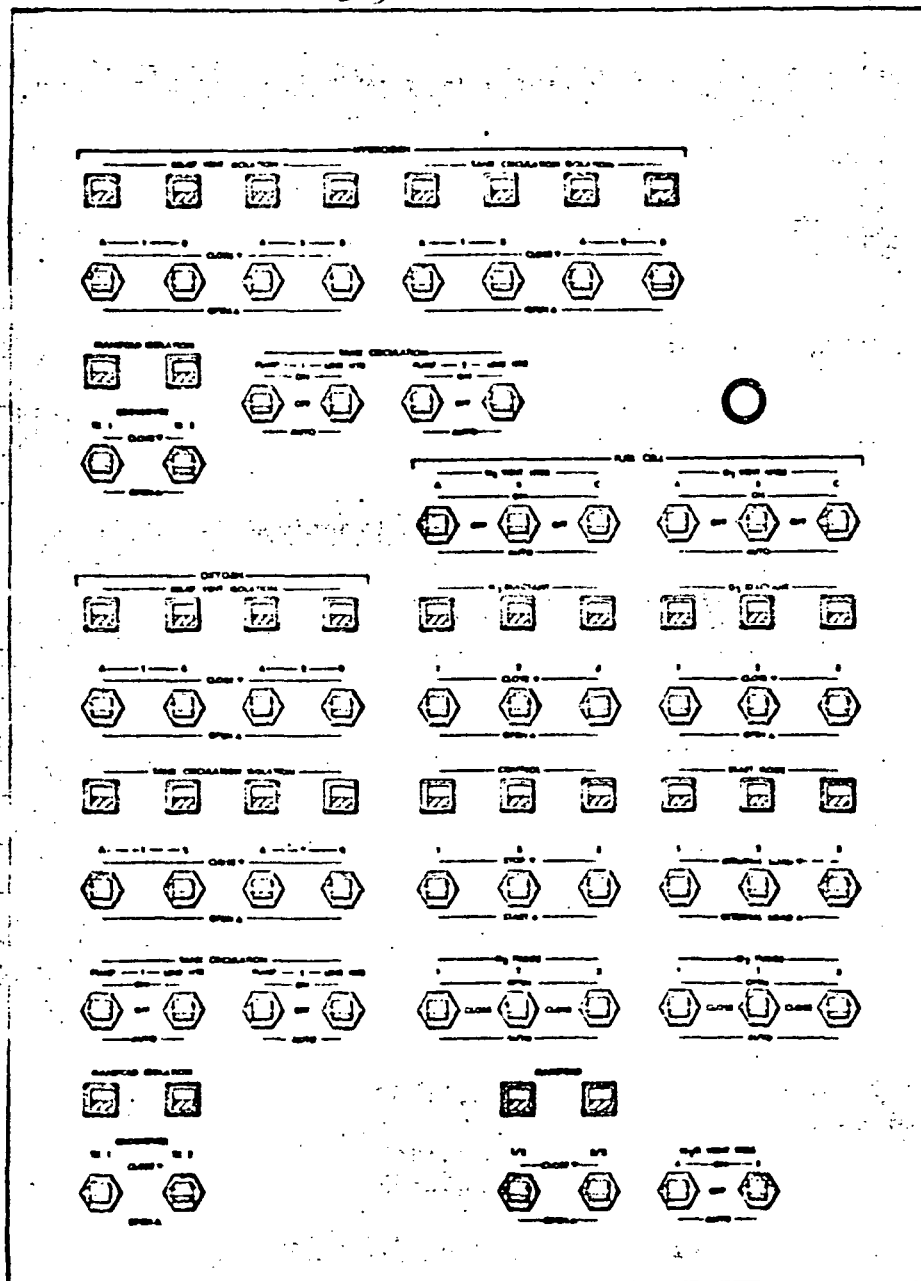
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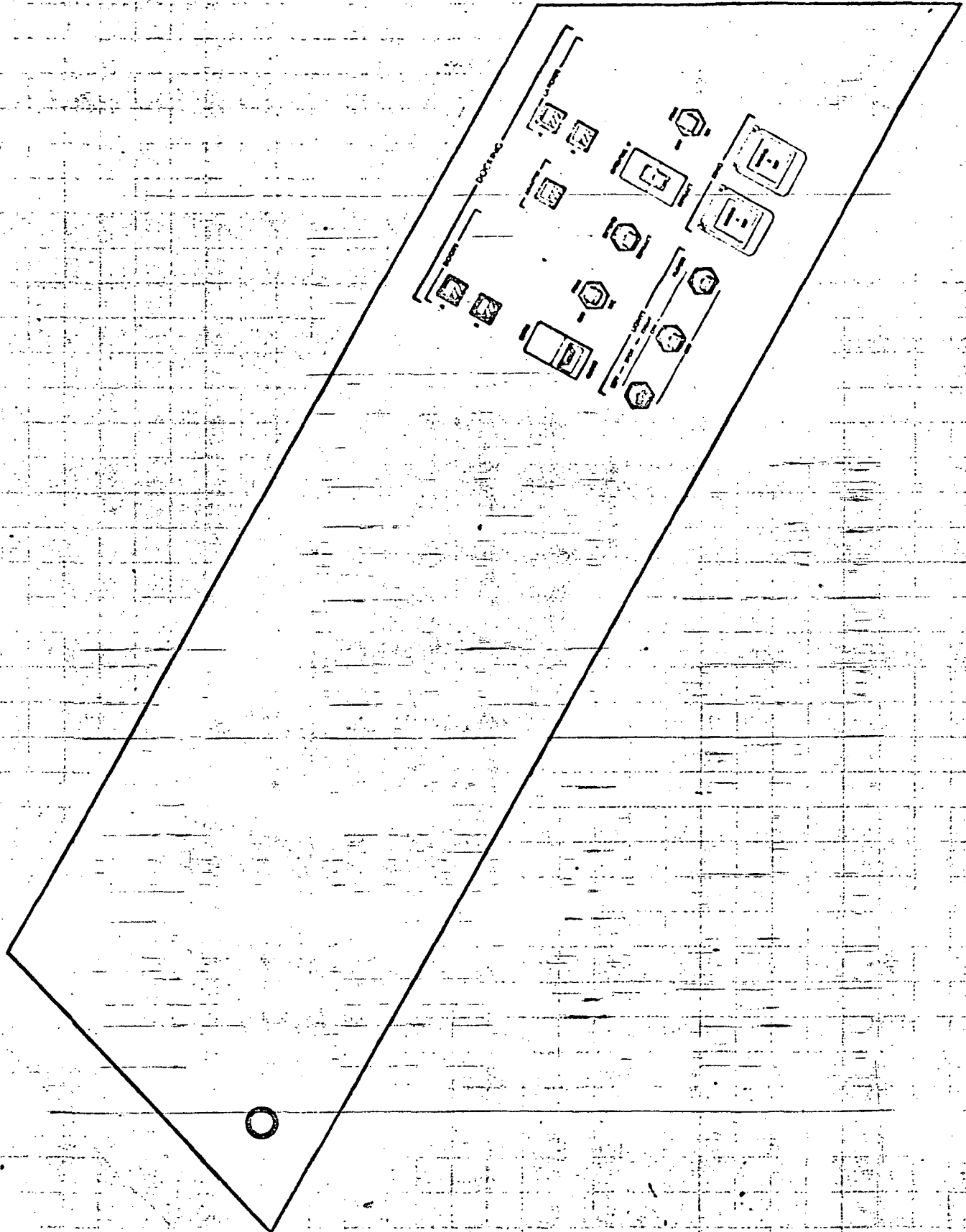
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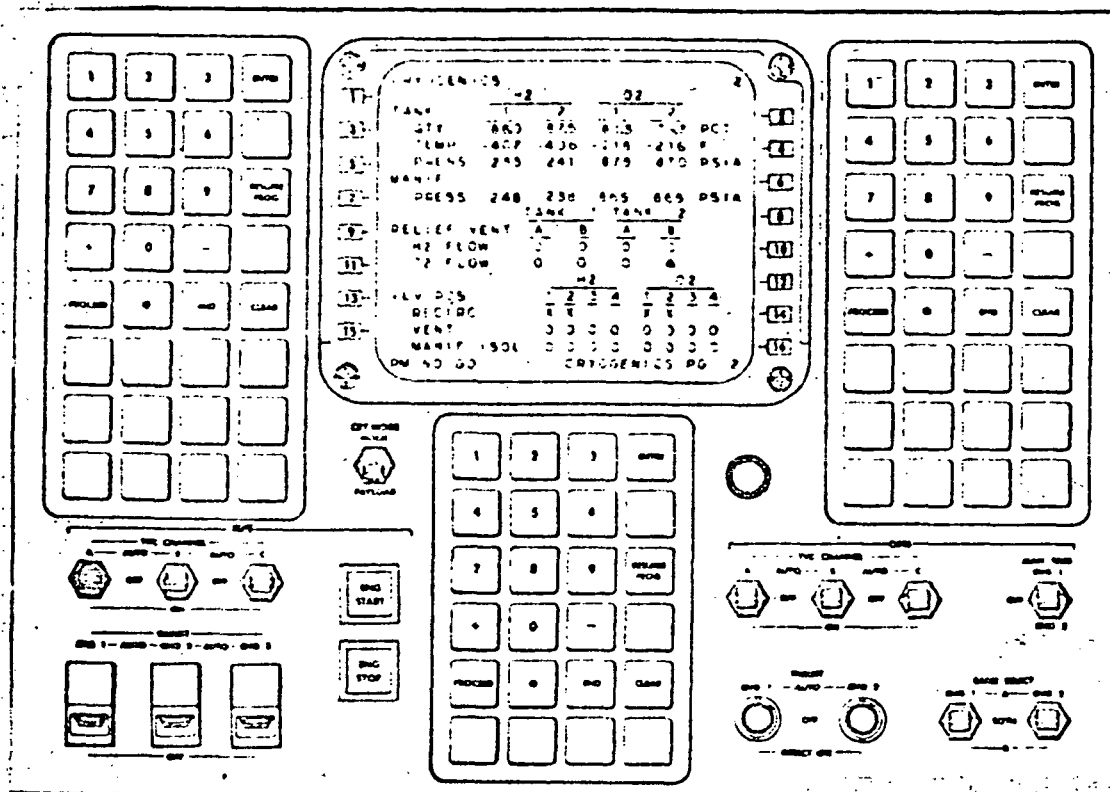
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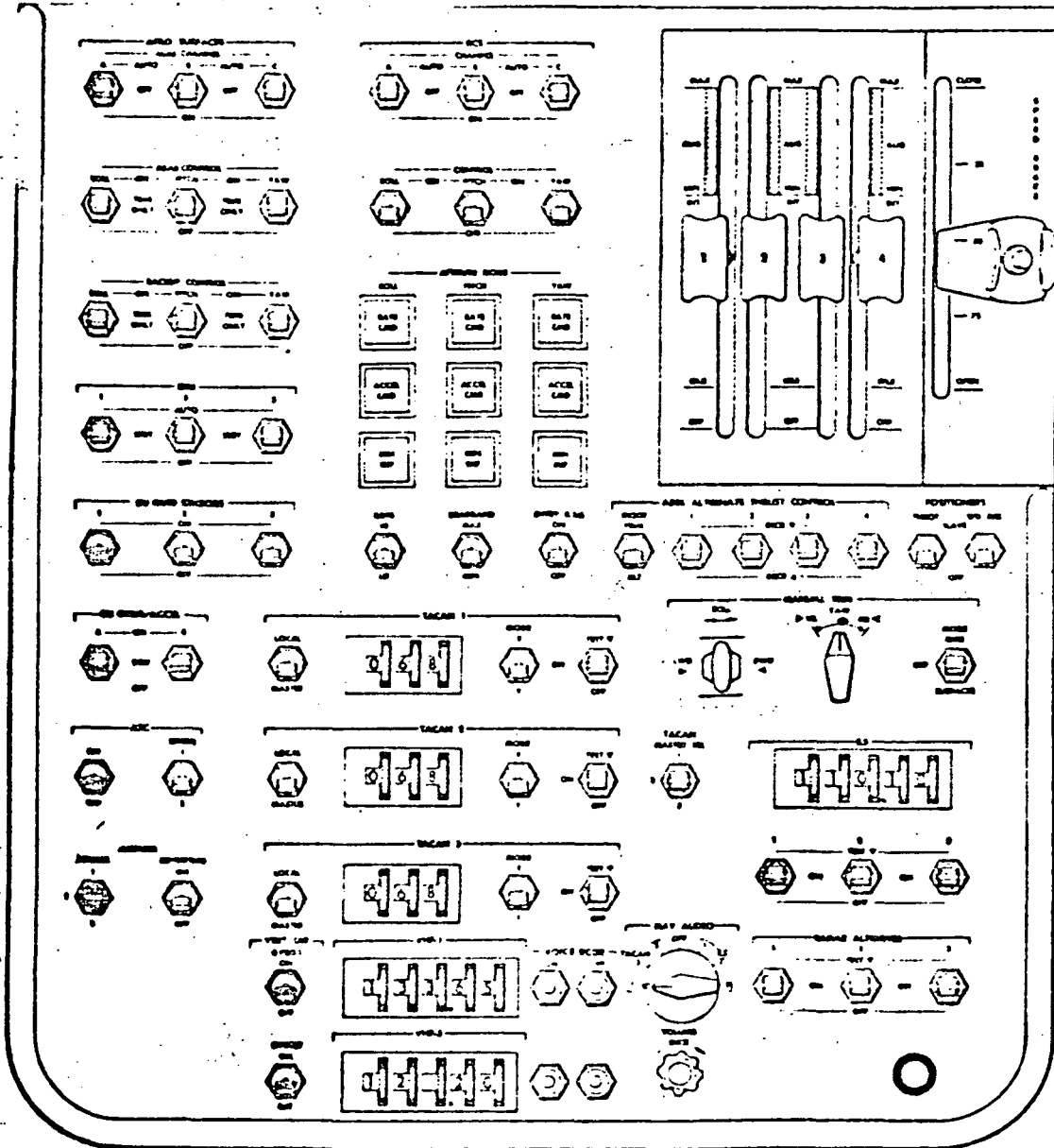
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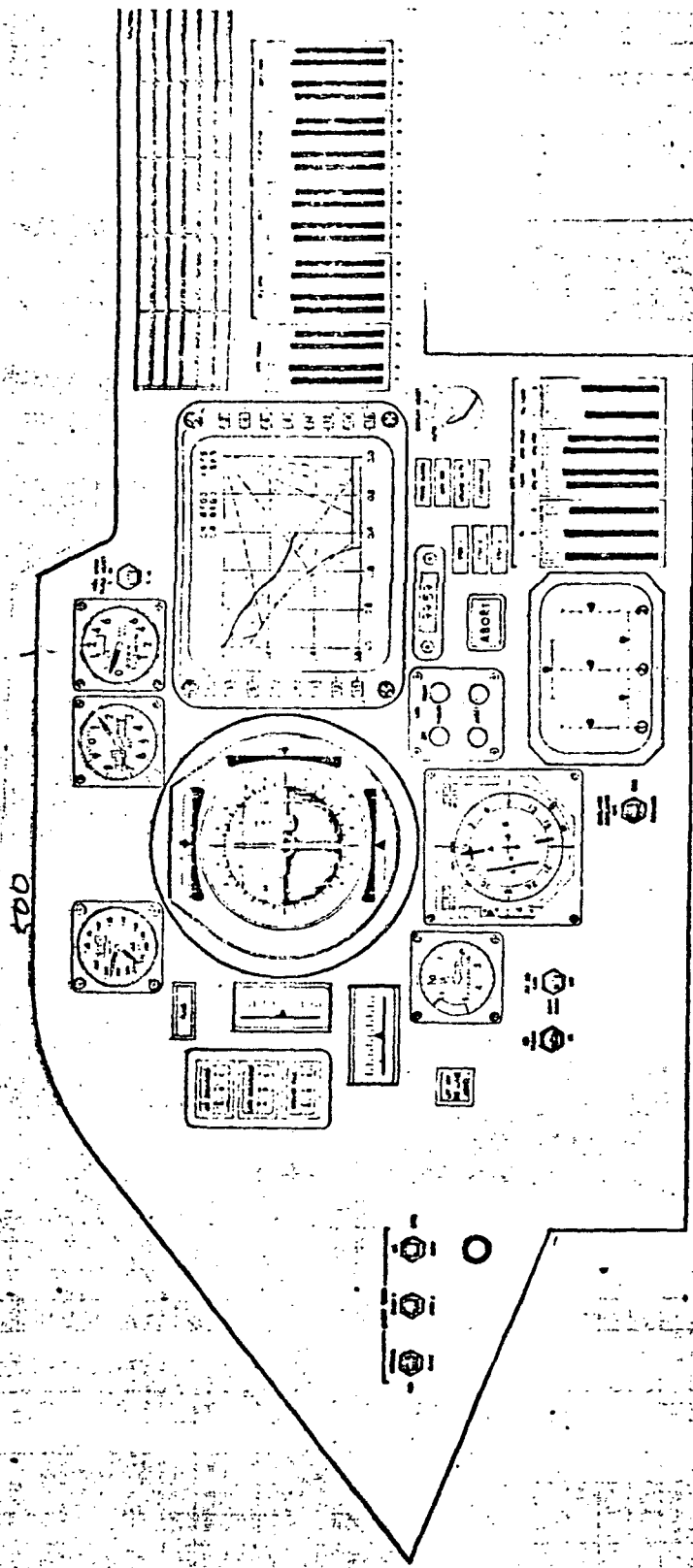
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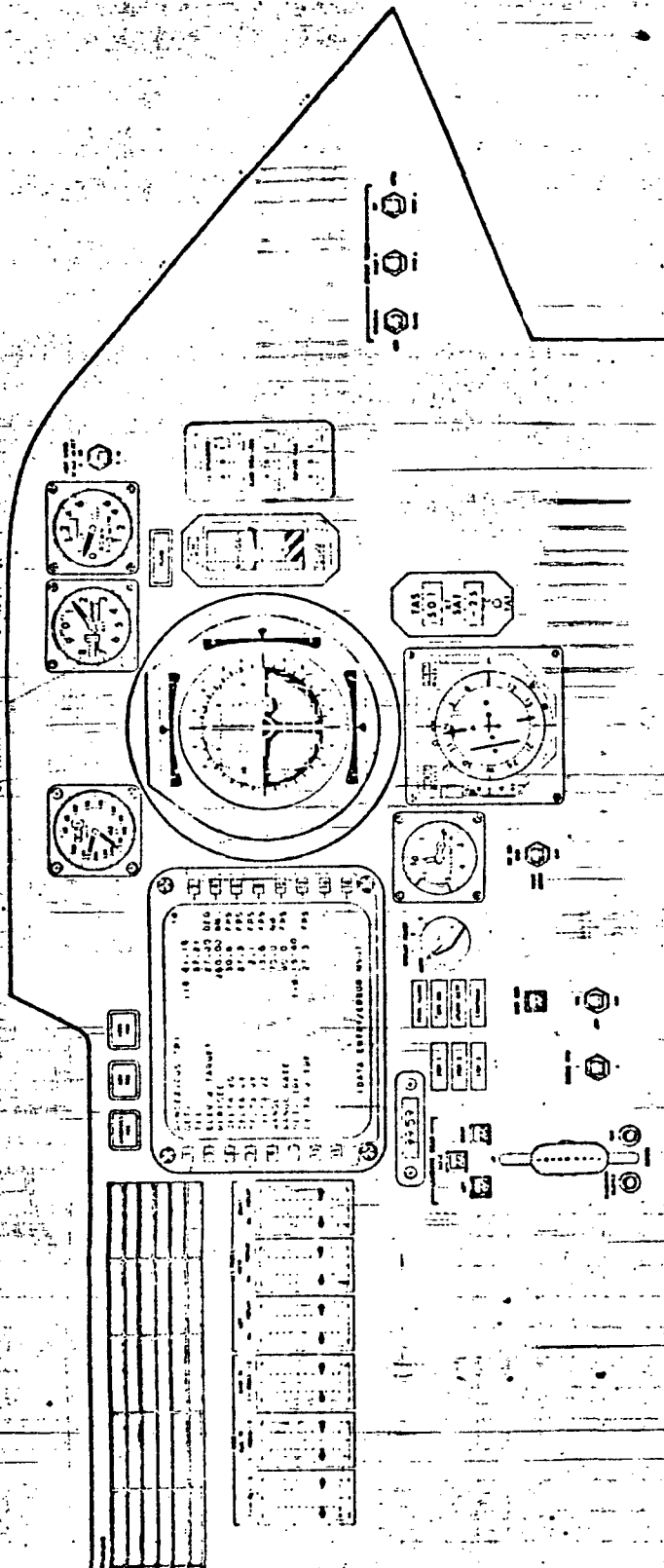
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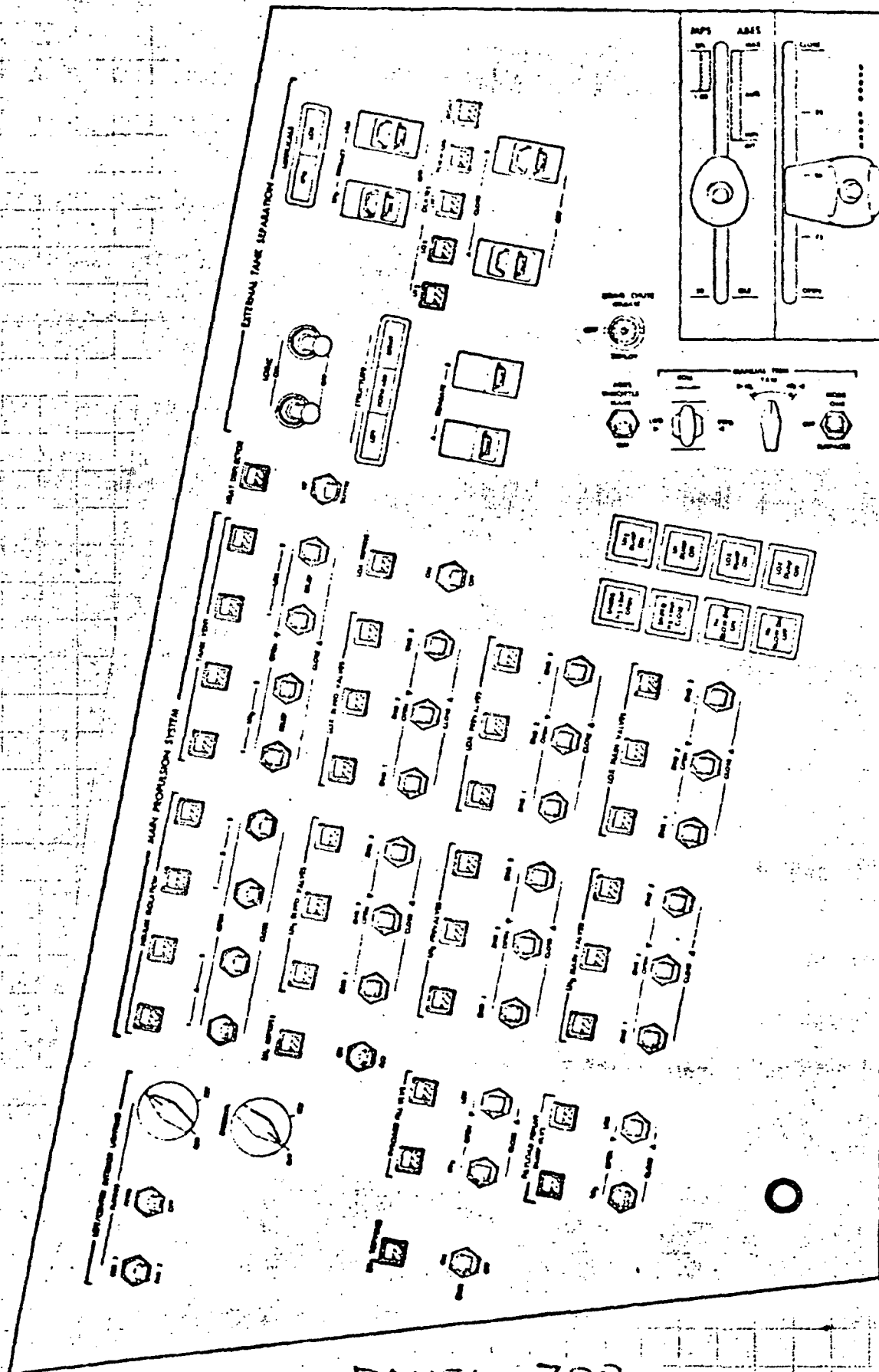
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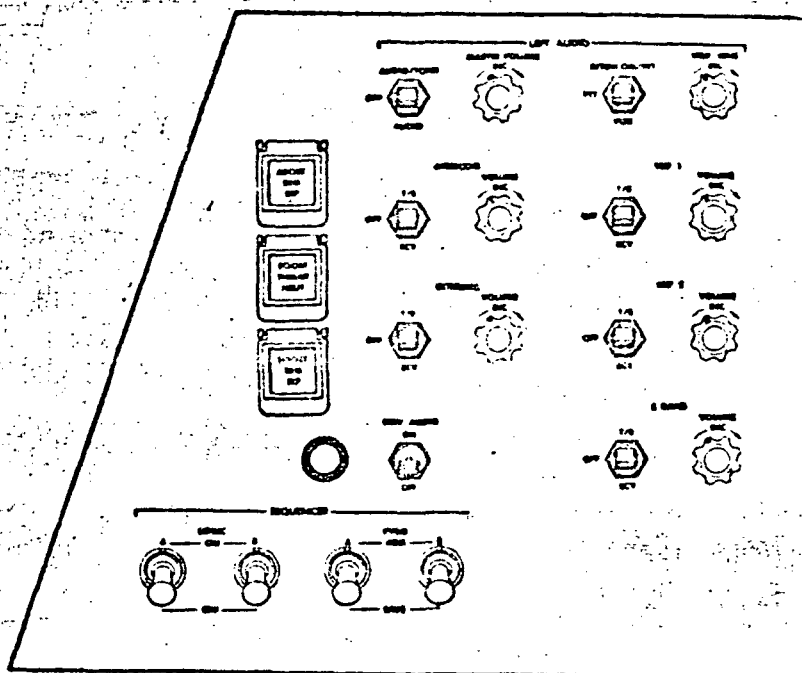
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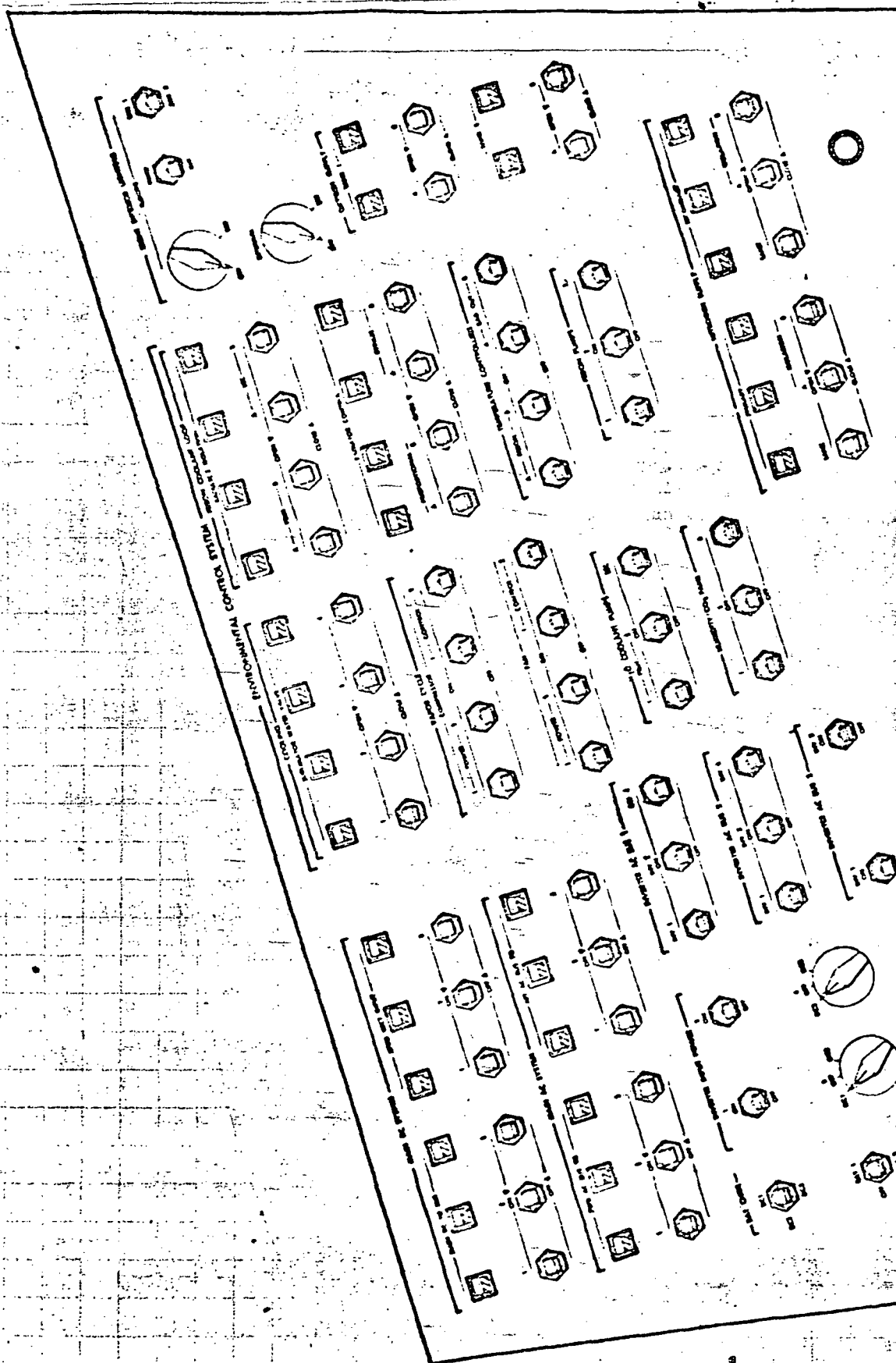


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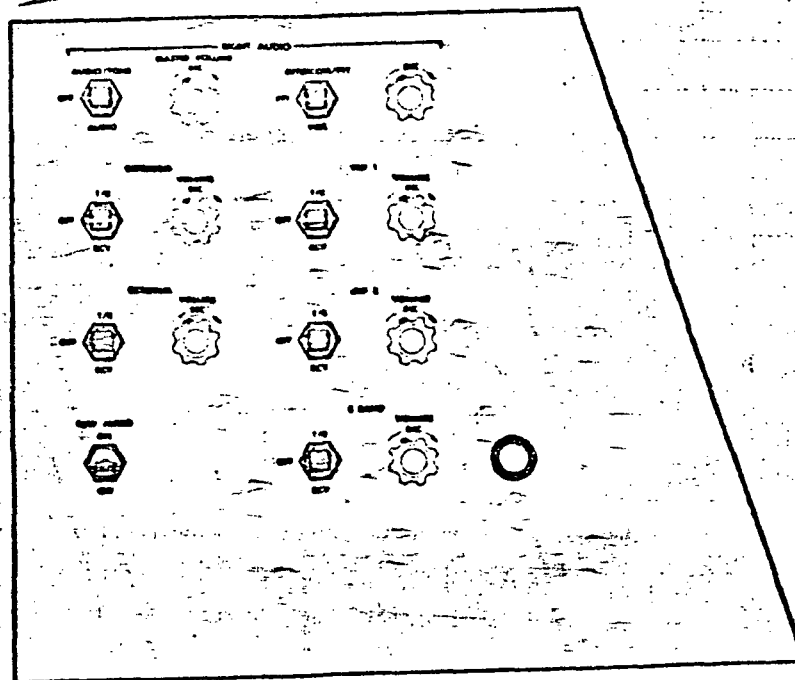
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RUDDER PEDALS

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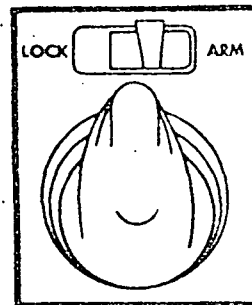
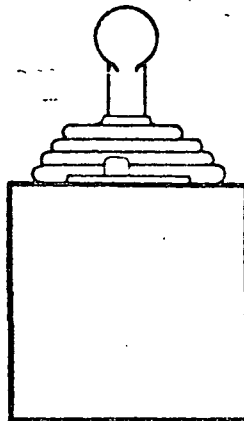
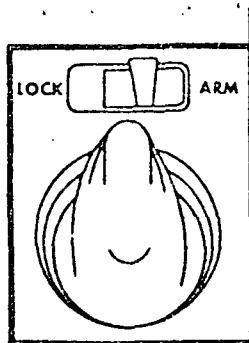
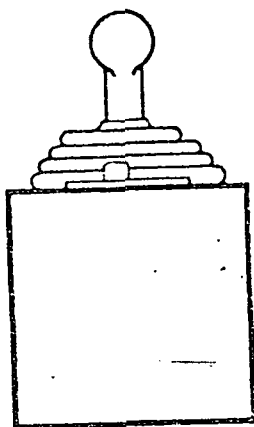
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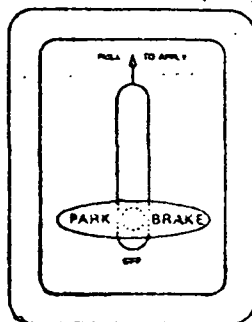


COMMANDER

PILOT

TRANSLATIONAL HAND CONTROL

ROTATIONAL HAND CONTROL



PARKING BRAKE

DATE

3/23/73

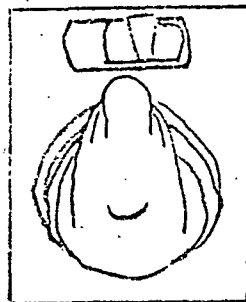
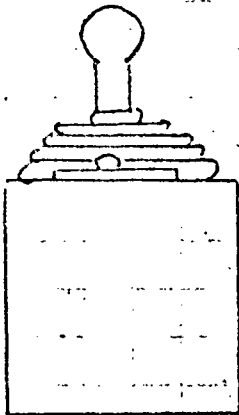
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MANIPULATOR STATION

TRANSLATIONAL HAND CONTROL

ROTATIONAL HAND CONTROL

MANIPULATOR CONTROLS (TBD)